STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*

BULLETIN NO. 61

ROCK WOOL FROM ILLINOIS MINERAL RESOURCES

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
1934

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*

BULLETIN NO. 61

ROCK WOOL FROM ILLINOIS MINERAL RESOURCES

GEOLOGY BY

J. E. LAMAR, B. S.,
Geologist and Head of the Non-Fuels Division, Geological Resource Section

and

H. B. WILLMAN, Ph. D.,
Associate Geologist, Non-Fuels Division, Geological Resource Section

CHEMISTRY BY

CHARLES F. FRYLING, Ph. D.,
Chemist, Non-Fuels Division, Geochemical Section

MINERAL ECONOMICS BY

WALTER H. VOSKUIL, Ph. D.,
Mineral Economist, Mineral Economics Section

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
1934

7
(31731)

Contents

Illustrations

Tables

Preface

The insulating industry is in its infancy and is now undergoing rapid development and expansion. Many kinds of insulating materials are being manufactured and placed on the market, each having certain merits by virtue of its properties, usefulness, and price. One of the most important of the insulating materials is rock wool which, because it is low in cost, fire-proof, vermin-proof, and possesses high insulating value, seems likely not only to retain its place as an insulating material but to improve its competitive position.

No rock wool is now being manufactured in the State of Illinois. Illinois, however, occupies a keystone position in the upper Mississippi Valley for the development of a rock wool industry if suitable raw materials can be found. It possesses or is close to major markets, it has adequate fuel resources, and it offers excellent transportation facilities.

In view of the above situation, the Illinois State Geological Survey undertook to ascertain whether or not the State possesses suitable raw materials in quantities and in locations which would provide a foundation for a new industry; one which would not be competitive with established mineral industries in the State; one which would utilize materials otherwise of little value; one which would increase employment through manufacturing, transportation and distribution channels and thereby bring large benefits to the people of the entire State; and one which would provide a product needed to promote the comforts of our civilization.

Field studies were begun in the summer of 1931, and with the installation of the Survey's new physical and chemical laboratories in December, 1931, group research was inaugurated in which the problem was attacked from the standpoints of geology, chemistry and mineral economics.

This report gives the findings of that investigation. It has been found that suitable raw materials exist in six major areas of the State, three in northern Illinois and three in southern Illinois, all of which are close to lines of transportation and large markets, and also in 15 other areas of probably lesser importance. In the course of the laboratory investigations, much new information has been obtained on the range of chemical composition permissible for the production of rock wool and on the factors which determine the texture, color, and other qualities of satisfactory rock wool. In addition to this information, this report discusses the general economic aspects of the rock wool industry and of the deposits of woolrock which have been discovered in Illinois, and outlines the procedure for ascertaining the commercial suitability of deposits for making rock wool.

In this study the Survey has received the hearty cooperation of the quarry companies of the State and property owners, to whom grateful acknowledgment is made. The Survey also wishes to acknowledge the helpful interest of the Illinois Chamber of Commerce, the Western Society of Engineers, the Illinois Society of Engineers, the Illinois Agricultural Limestone Association, and the Illinois Clay Manufacturers Association.

The geological work was placed under the charge of Mr. J. E. Lamar, Geologist and Head of the Non-Fuels Division of the Survey, in collaboration with Dr. H. B. Willman, Associate Geologist, who were assisted in the field by Dr. C. E. Dutton, Associate Geologist, and Mr. H. W. Scott, Assistant Geologist. The chemical work was under the general supervision of Dr. F. H. Reed, Chief Chemist, the physical chemical research being executed by Dr. Charles F. Fryling, Chemist, who was assisted by Mr. F. V. Tooley. The analytical work was assigned to Dr. O. W. Rees, Associate Chemist, who was assisted by analysts L. D. McVicker and C. W. Westerberg. The study of the economics of the rock wool industry was made by Dr. Walter H. Voskuil, Mineral Economist. To the hearty and effective cooperation of these members of the technical staff who participated in this group research is due the success of this undertaking.

The Survey will be glad to answer inquiries in regard to the information contained in this report and assist, so far as it can properly do so, those who become interested in establishing a rock wool industry in this State.

(Signed) M. M. Leighton, *Chief*
Illinois State Geological Survey

Urbana, Illinois,
June 28, 1934.

Part I

INTRODUCTION

CHAPTER I

Illinois is peculiarly fitted for the development of a rock wool industry. Geographically the State is well located with reference to the major market districts of the upper Mississippi valley states and it possesses excellent rail and water transportation facilities to these districts. The State is further favored by possessing adequate fuel for use in rock wool manufacture. The present report describes a number of deposits which offer promise as sources of rock wool making materials; detailed explorations will probably reveal others.

Rock wool is finding an increased number of uses in construction, industry, and transportation. A particularly promising field for the use of rock wool is the insulation of houses to make them warmer in winter and cooler in summer, and, therefore, the possibility of an expansion of new house construction in the near future offers an attractive potential market. A similarly promising market lies in the possibility of modernization, by the installation of proper insulation, of existing homes, over two million of which lie within the Illinois market area, especially in the Chicago, Milwaukee, St. Paul-Minneapolis and St. Louis market districts.

Nature of the Report

This report includes a discussion of chemical, geological, and economic studies of the rock wool making materials of Illinois. It deals primarily with materials occurring as bedrock or consolidated rock, because some of these can probably be used in the customary manner and in the usual equipment now employed for making rock wool. Unconsolidated rock materials such as gravel, glacial clay and loess are described only briefly because they are not known to have been used commercially for making rock wool and because their physical nature raises a question as to whether they can be successfully converted into rock wool by existing methods of manufacture, even if shown suitable by laboratory tests.

A discussion is included concerning the possibility of mixing two bedrock materials or a bedrock and an unconsolidated material so as to obtain a suitable mixture for making rock wool, dealing especially with those samples in which the amount and nature of material to be added appear to be such that the melting operation can probably be carried out in the type of cupola customarily used for rock wool production.

FIG. 1. Map showing general location of areas containing woolrock and sub-woolrock. (See Chapters II-IV for precise locations.)

Areas containing woolrock and sub-woolrock deposits are provisionally classified as "favorable economic areas" and "less favorable economic areas", based on their distances from fuel supplies and markets. Thirteen districts within the Illinois market area are delineated (Fig. 31, p. 212) and the comparative market capacity of these districts is evaluated.

Summary of Findings

The feasibility of producing rock wool from the mineral resources of Illinois has been investigated and it has been found that the most promising formations for the occurrence of woolrock in certain places are the Maquoketa shale and limestone of Ordovician age, the Niagaran dolomite of Silurian age, the Bailey limestone of Devonian age, and the impure limestones of Pennsylvanian ("Coal Measures") age. There are also sand and gravel deposits and pebbly glacial clays which are suitable from the standpoint of composition but the feasibility of using these materials for rock wool manufacture depends on the solution of engineering problems involved in the melting process and upon economic factors.

An experimental method, by means of which rock wool of commercial quality can be produced on a small scale, was developed. Twenty-two typical rock samples, taken from Illinois bedrock deposits and subjected to this experimental blowing test, were found to yield rock wool.

The effects of changing the pouring temperature, rate of pouring, and steam blast pressure on the characteristics of rock wool were determined.

The limits of composition suitable for the production of rock wool under standardized experimental blowing conditions were determined for the four-component system consisting of silica, alumina, lime, and magnesia. The dark color of certain rock wools was traced to the presence of compounds of iron and sulphur in the wools, and the efficacy of longer heating at elevated temperatures for the removal of this color was demonstrated.

Measurements of fiber diameters were found useful for evaluating the quality of rock wool, and the variations of this quantity, with changes in the operating variables and the ratio of acidic to basic components, were determined. Satisfactory rock wools were produced from silica and lime within rather narrow limits of composition. The presence of magnesia or alumina is not, therefore, essential.

The determination of the carbon dioxide content of rocks was found to afford a simple and satisfactory means of obtaining a preliminary evaluation of the rock wool possibilities of a given rock sample. All rock samples containing from 20 to 30 per cent CO_2 yielded rock wool when subjected to the experimental blowing tests. The CO_2 values delimit, quite accurately, the entire range of satisfactory compositions in the SiO_2, Al_2O_3, CaO, and MgO system.

The literature on mineral wool is summarized under the headings of composition, manufacturing practice, and heat conductivity. The physical transformations effected during the blowing operation are described.

The possibility of producing rock wool from mixtures of rocks is considered and the limitations imposed by compositional requirements, manufacturing equipment, and economic considerations are indicated.

Twenty-one areas in which the outcropping bedrock formations contain woolrocks, sub-woolrocks, or both, are shown in figure 1. Data regarding their economic favorability and probable workability are herein reported. The deposits described are thought to be typical of bedrock materials available in Illinois for rock wool manufacture. Detailed prospecting and exploration will doubtless reveal additional suitable deposits.

Procedure for Ascertaining Commercial Suitability of Deposits for Making Rock Wool

Eight major items are involved in the evaluation of the commercial suitability of any given deposit for rock wool manufacture, as follows:

1) The size and probable growth of the available market.

2) The cost of obtaining suitable fuel at the plant site.

3) Transportation costs on finished product from the proposed point of production to markets.

4) Demonstration, by means of detailed exploration, of the existence of a deposit of such size and character as to be economically workable and of satisfactory chemical composition and physical nature.

5) Purchase cost of quarry and plant site.

6) Cost of quarrying and delivering raw materials to the factory site.

7) Proof, through the erection and operation of a pilot plant, that representative material from the deposit it is proposed to exploit is satisfactory for rock wool production.

8) Determination, by pilot plant experimentation, of the best method for manufacture, and of the nature of equipment to be used in the commercial scale plant.

Definition of Terms

Mineral wool.—This is a general term to designate insulating materials composed of silicates in the form of fine, glassy fibers.

Slag wool.—A mineral wool made from slag.

Glass wool.—A mineral wool generally made from soda-lime glass.

Rock wool.—A mineral wool made from rock.

Woolrock.—In this report "woolrock" is used to define rock, which on proper treatment without the addition of other materials yields rock wool.

The limits of composition of woolrock (composed predominantly of silica, alumina, lime, magnesia, and carbon dioxide) have been determined under a specified set of conditions, and in this report the statement that a given rock is a woolrock refers only to the fact that its composition falls within the specified limits. It has been found that Illinois rocks whose carbon dioxide content is between 20 and 30 per cent are in most cases woolrocks. When detailed analytical data are not available, Illinois rocks having carbon dioxide contents between these limits are tentatively classified as woolrocks.

Sub-woolrock.—A sub-woolrock is defined in this report as a rock composed predominantly of the same substances as a woolrock, but requiring the addition of moderate amounts of rock materials, such as shale, sandstone, limestone or dolomite, to yield a mixture, the composition of which lies within the composition limits of woolrock. The classification of Illinois rocks as sub-woolrocks has been arbitrarily made on the basis of carbon dioxide contents. Carbon dioxide limits of 15 to 20 and 30 to 38 per cent have been chosen.

Flux rock.—The term flux-rock is used in this report to designate a rock which can be added to a sub-woolrock to produce a mixture having the composition of a woolrock.

Bulk density.—This term is used to designate the weight per unit volume of the aggregate of fibers, shot, and entrapped air pockets, which constitutes mineral wool.

Part II

GEOLOGICAL INVESTIGATIONS

By J. E. Lamar, B.S., and H. B. Willman, Ph.D.

Under the supervision of

M. M. Leighton, *Chief Geologist*

CHAPTER II.—WOOLROCK AND SUB-WOOLROCK DEPOSITS IN ECONOMICALLY FAVORABLE AREAS

INTRODUCTION

The studies of the State's resources of rock wool making materials discussed in chapters II, III, IV and V had three major objectives: (1) to discover deposits of woolrock in areas favorably located with reference to transportation, markets, and fuel supply ("economically favorable areas," p. 221); (2) if woolrock deposits were lacking in economically favorable areas, to discover in these areas rock deposits whose materials might be combined to yield mixtures suitable for making rock wool; and (3) to secure general information regarding the rock wool making possibilities of the rock formations in the remaining less economically favorable parts of the State.

As the results of the present study show that an adequate supply of woolrock is available in Illinois, the geological section of the report discusses in detail primarily those deposits which have proved to be woolrock or sub-woolrock in economically favorable areas. However, a few less economically favorable areas containing woolrock or sub-woolrock, for which data are at hand, are described. Further, data on the chemical composition of deposits which are neither woolrock nor sub-woolrock are presented for the benefit of those who wish to consider the possibility of rock mixtures for the production of rock wool.

For convenience, the areas studied are classified and discussed as follows: (1) economically favorable areas, and (2) less economically favorable areas. The areas are further classified according to whether they contain deposits of woolrock or only sub-woolrock and also according to the workability of these deposits.

Areas classified as containing "workable deposits" of woolrock or sub-woolrock are those which are thought to contain one or more deposits of considerable size that can be exploited by customary mining or quarrying methods. Areas classified as containing deposits whose workability is uncertain are those for which less information is available regarding such items as thickness of deposits, areal extent of deposits, lateral variations in composition of woolrock or sub-woolrock strata, and mining or quarrying problems or costs. However, detailed exploration and prospecting will supply much data not now available and may reveal the existence of workable deposits of woolrock in some of these areas.

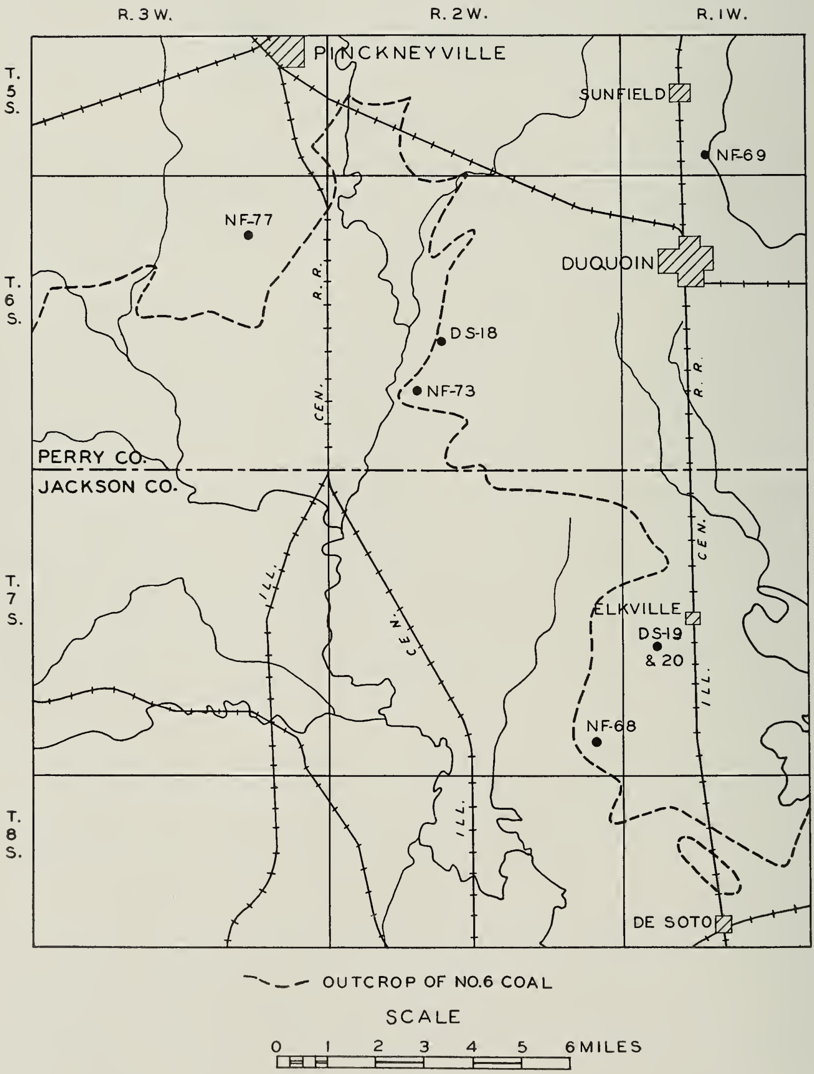


FIG. 2. Map of DuQuoin area showing locations where samples (DS-18 to 20, and NF-68, 69, 73, and 77) were collected and the approximate line of outcrop of Herrin (No. 6) coal. (G. H. Cady, Illinois State Geol. Survey Coop. Mining Sur. Bull. 31, 1927, Pl. I.)

Deposits of Woolrock, With or Without Sub-Woolrock

WORKABLE DEPOSITS

DuQuoin Area

(Perry and Jackson counties)

CAPROCK OF COAL NO. 6 IN THE VICINITY OF DUQUOIN

SUMMARY

The limestone caprock of coal No. 6 is exposed in a number of large strip pits from which coal No. 6 is mined in the vicinity of DuQuoin, Pinckneyville, and Elkville. Samples of the caprock from some of the mines were found to be woolrock; samples from other mines are sub-woolrock. The thickness of the caprock ranges from zero to a known maximum of about 23 feet. Commercial exploitation of the thicker caprock appears possible.

DESCRIPTION OF OUTCROPS SAMPLED

In order to evaluate the rock wool making possibilities of the limestone caprock above coal No. 6, six samples were obtained from five mines distributed throughout the area (Fig. 2).

Pyramid Coal Company.—The strip mine of the Pyramid Coal Company lies a few miles south of Pinckneyville and was sampled from the mine face in the NW. ¼ sec. 11, T. 6 S., R. 3 W., where the following section was measured:

Geologic section in mine of Pyramid Coal Company

		Thickness *Feet*
5.	Clay (loess and till)	15±
4.	Shale, black	6–8
3.	Limestone, dense, dark gray, argillaceous. Possibly somewhat more limy in lower 3 feet than in overlying beds. Upper 3 feet shaly and grades into shale. (Sample *NF*-77)	15
2.	Shale, gray	3–5
1.	Coal, Herrin (No. 6)	

In general the clay and shale overburden on the limestone averages 20–25 feet throughout the mine.

Sample *NF*-77, (Table 1, p. 59) taken from the 15-foot bed of limestone was found to be a woolrock (pp. 162, 165).

United Electric Coal Company.—Two samples of the caprock of Herrin (No. 6) coal were obtained from the strip mine of the United Electric Coal Company, southwest of DuQuoin. The sequence of strata is as follows:

Geologic section of mine face in the NE. ¼ NW. ¼ NE. ¼ sec. 29, T. 6 S., R. 2 W.

	Thickness Feet	Thickness Inches
6. Shale, clay (till) and sand	15–20	
5. Coal		2–3
4. Shale, gray	1	
3. Limestone, dark gray, argillaceous (Sample *NF-73*)	15	
2. Covered, probably shale	5±	
1. Coal, Herrin (No. 6)		

Geologic section of mine face in the NW. ¼ NE. ¼ SW. ¼ sec. 21, T. 6 S., R. 2 W.

4. Clay (till and loess)	15±
3. Limestone, gray, fine grained, in beds 6–8 inches thick (Sample *DS-18*)	15
2. Shale, dark gray, in beds 1–4 inches thick	6
1. Coal, Herrin (No. 6)	

Sample *NF-73* (Table 1 and pp. 163, 166) proved to be a woolrock. Sample *DS-18* (Table 1 and p. 174) is a sub-woolrock which requires the addition of a small amount of shale or sandstone to yield a mixture whose chemical composition lies within the composition limits of woolrock. The shale overlying the limestone and, where present, the shale underlying it afford a convenient source of material for admixing purposes.

Gayle Coal Company (Peabody Coal Company).—The strip mine of the Gayle Coal Company lies south and a little east of Sunfield. This mine was sampled from the face exposed near the center sec. 32, T. 5 S., R. 1 W., where the following geologic section was measured:

Geologic section in mine of Gayle Coal Company

		Thickness Feet
6. Clay (loess) 5. Shale	(average about 15 feet)	10–20
4. Limestone, gray, probably not highly argillaceous	Sample *NF-69*	2
3. Limestone, dark gray, argillaceous	Sample *NF-69*	7
2. Shale, gray		6
1. Coal, Herrin (No. 6)		

Sample *NF-69* (Table 1 and p. 174) proved to be a sub-woolrock which requires the addition of shale or sandstone.

Truax-Traer Coal Company.—The two mines of this company are located a short distance southwest of Elkville. The section sampled in the Black Servant pit is as follows:

Geologic section of mine face in the NW. ¼ NE. ¼ sec. 19, T. 7 S., R. 1 W.

		Thickness Feet
5.	Clay, pebbly (till)	15±
4.	Shale, dark gray, locally sandy (Sample *DS-20*)	12
3.	Limestone, fine grained, dark gray, in beds 10–12 inches thick (Sample *DS-19*)	12
2.	Shale, gray	2–3
1.	Coal, Herrin (No. 6)	

Sample *NF-68* was obtained from 4 feet of the caprock of coal No. 6 in the Forsythe pit in the NE. ¼ NW. ¼ sec. 36, T. 7 S., R. 2 W. The face was badly slumped and a detailed section of the beds associated with the limestone could not be made. The overburden on the limestone is estimated to be 30–35 feet of shale and clay.

Both samples *DS-19* and *NF-68* (Table 1) proved to be sub-woolrocks which require the addition of shale or sandstone. Shale (Sample *DS-20*) for such purposes is available from associated beds.

GENERAL CHARACTER OF THE LIMESTONE CAPROCK OF COAL NO. 6

The lithologic character of the limestone caprock of coal No. 6 varies widely in short distances. Many variations can usually be seen along the exposed faces in the strip mines. In general the limestone is a fine or locally medium grained, dark gray, argillaceous stone; in some places it occurs in heavy layers 3 feet or more thick, in others the beds range from 6 to 12 inches in thickness. Where the limestone locally grades upward into the overlying shale, the upper part is usually thin bedded. The more argillaceous stone has a tendency to spall and split when exposed to the weather.

The thickness of the limestone ranges up to a known maximum of 23 feet; a common thickness where the bed is well developed is 12 to 15 feet. Local variations in thickness are pronounced in some tracts as shown in figure 3. In some places an increase or decrease in the thickness of the limestone is compensated by a corresponding decrease or increase in the thickness of the shale which lies between it and the coal, but in other places the thickness varies because of irregularities in the top of the bed. The stone is of irregular distribution and is absent from areas of considerable size.

The limestone is commonly overlain by dark gray shale, which was observed to reach a maximum thickness of 15 feet at one place; locally, however, the shale is absent and pebbly clay rests directly on the limestone.

Locally records of borings show above coal No. 6 two or more limestone beds of variable thickness which are usually thin and are separated by shale.

The chemical composition of the limestone is variable, but available data indicate the formation to be lowest in carbonates west of DuQuoin and south of Pinckneyville. Two samples, *NF-73* and *77*, obtained in this region were

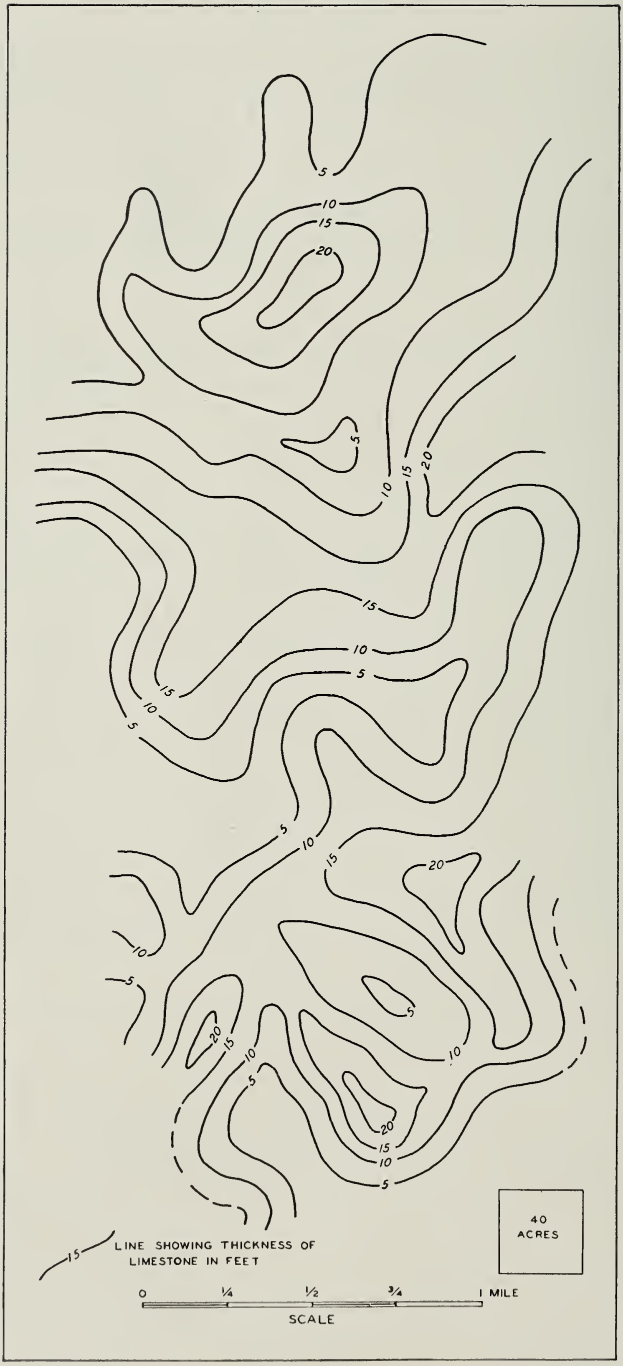


FIG. 3. Map showing the marked lateral variations in thickness of the caprock of coal No. 6 in a part of the DuQuoin area. The location of the area can not be given because the map is based on confidential coal test borings.

woolrocks and a third, *DS-18,* was sub-woolrock. Elsewhere the samples of caprock studied are sub-woolrocks.

In general the dull, very fine grained, almost black, argillaceous phase of the caprock limestone has a comparatively low carbonate content and is therefore likely to be a woolrock. Other beds having a medium grained texture are commonly higher in carbonate content as are also strata which are dotted with white specks, usually fragments of fossils. Some of these beds may be woolrocks, but most of them are probably sub-woolrocks.

The dark gray or almost black color of the limestone is probably due to included carbonaceous material.

DEVELOPMENT CONSIDERATIONS

The most favorable regions for the commercial development of the caprock of coal No. 6 correspond roughly with the area where coal No. 6 can be mined by open pit operations. Such areas have been described in other reports[1] and in general fall close to the line of outcrop of the coal which is shown in figure 2. A narrow tract ¼ to ½ mile wide from which coal No. 6 and its caprock have been largely eroded[2] extends from a point 1½ miles northeast of Sunfield in the NW. ¼ sec. 21, T. 5 S., R. 1 W., almost due south along the east edge of the town of DuQuoin to a point at the center of the south line of sec. 29, T. 6 S., R. 1 W., a distance of 8 miles. This eroded area lies along the crest of an up-fold in the bedrock known as the DuQuoin anticline. Areas of strippable coal occur in places along the margin of the eroded tract and constitute possible areas where the caprock may also be secured.

The recovery of the caprock of coal No. 6 in connection with coal stripping operations appears worthy of consideration in those areas where the limestone is a woolrock or sub-woolrock and is present in sufficient quantities to make it profitably exploitable. Because of the value of the limestone and the consequent reduction of coal stripping costs in such areas, some tracts of coal which have been avoided because of thick overburden containing a thick limestone may prove to be economically strippable.

The amount of limestone recovered during the course of a normal coal stripping operation might be greater at some times than the requirements of a rock wool plant, at others less. This together with the fact that the potential life of a coal stripping operation may be less than that of a rock wool plant, suggests that the caprock would probably have to be stored in piles and used as needed. An acre tract underlain by woolrock averaging 6 feet in thickness would yield about 20,000 tons of material which when processed would give about 10,000 tons of rock wool. Thus a plant producing 30,000 tons of

---

[1] Culver, H. E., Preliminary report on coal stripping possibilities in Illinois: Illinois State Geol. Survey Coop. Mining Series, Bull. 28, 1925.
Cady, G. H., Coal stripping possibilities in southern and southwestern Illinois: Illinois State Geol. Survey Coop. Mining Series, Bull. 31, 1927.

[2] Fisher, D. J., Structure of Herrin (No. 6) coal seam near DuQuoin: Illinois State Geol. Survey Report of Investigations No. 5, 1925, Plate I.

rock wool yearly would require roughly the amount of stone obtainable from about 3 acres of such a deposit. Most coal strip mines each year work out a considerably larger area than this.

Large areas of coal have already been stripped and the limestone, shale, and clay of the overburden are irregularly mixed in waste piles. It is not known whether the limestone at any place forms a large enough proportion of these piles to be profitably salvaged. In many of the piles, it is a comparatively minor constituent.

The production of woolrock independent of the production of coal is doubtless possible in those places where the caprock limestone is thick and may be particularly worth while in any areas which for various reasons are considered unsatisfactory for coal stripping.

A large part of the areas favorable for stripping coal No. 6 and in general, therefore, for the recovery of the caprock limestone, is leased or owned by coal companies. These companies have done extensive test drilling and have much data regarding the distribution and thickness of the limestone. Such data where available are valuable in outlining the quantity of rock obtainable from a given area, but should be supplemented by other borings in favorable areas to secure samples from which to determine the chemical composition of the limestone and its possible suitability for making rock wool. The variable composition of the limestone makes careful prospecting imperative.

The Missouri Pacific and Illinois Central railroads furnish transportation in the area.

Freeburg Area
(St. Clair County)

LIMESTONE CAPROCK OF COAL NO. 6 IN THE STRIP MINE OF UNITED ELECTRIC COAL COMPANY

SUMMARY

The limestone caprock of coal No. 6 in the strip mine of the United Electric Coal Company, located about 3 miles southeast of Freeburg (Fig. 4), at some places comprises a single limestone stratum 12 to 15 feet thick and in others 2 to 4 limestone strata interbedded with shale. One sample of the caprock was found to be a woolrock and another a sub-woolrock. Exploitation of the caprock where it is well developed in connection with coal stripping seems feasible.

DESCRIPTION OF OUTCROPS SAMPLED

Two exposures of the limestone caprock of coal No. 6 were sampled in the United Electric Coal Company's strip mine where the following sequences of beds were observed:

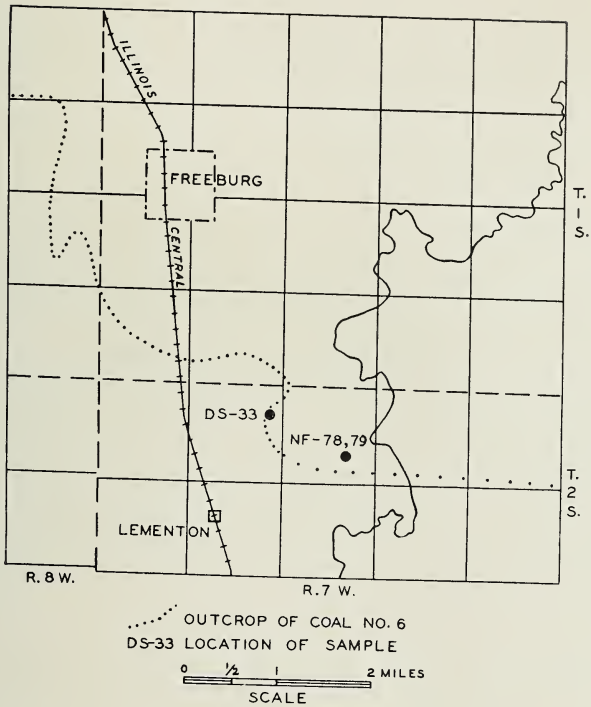


FIG. 4. Map of the Freeburg area showing locations where samples were taken and the approximate line of outcrop of coal No. 6. (G. H. Cady, Illinois State Geol. Survey Coop. Mining Inv. Bull. 31, 1927, Pl. I.)

Exposure in SE. ¼ sec. 4, T. 2 S., R. 7 W.

			Thickness	
			Feet	*Inches*
11.	Clay, pebbly, and silt (till and loess)		10–15	
10.	Shale, gray, calcareous in basal portion; grades into bed below		8	
9.	Limestone, dark gray, argillaceous		2	
8.	Shale, dark gray, with coaly streaks	Sample *NF-78*		6
7.	Limestone, dark gray			2–4
6.	Shale, gray			1
5.	Coal			4
4.	Shale, black			8
3.	Limestone, dark gray, with light specks		3–4	
2.	Shale, gray		3–5	
1.	Coal, Herrin (No. 6)			

Sample *NF-79* (Table 1, p. 61; also pp. 163, 166) taken from beds 3 and 9, totaling 5 feet, is woolrock. Sample *NF-78*, totaling 22 inches, represents the various materials between beds 3 and 9.

Exposure in SE. ¼ NE. ¼ sec. 5, T. 2 S., R. 7 W.

	Thickness *Feet*
9. Clay, pebbly (till)	10
8. Shale, gray, upper part yellow	3
7. Limestone, brownish gray, argillaceous	1
6. Shale, gray	2
5. Limestone, gray, fine grained	1
4. Shale, gray, containing interbedded limestone layers	3
3. Limestone, gray, fine grained	2
2. Shale, carbonaceous	4
1. Coal, Herrin (No. 6)	

Sample *DS-33* (Table 1), taken from beds 3, 5, and 7, totaling 4 feet in thickness, is sub-woolrock which requires the addition of clay, shale, or sandstone to yield a mixture whose chemical composition lies within the composition limits of woolrock.

GENERAL CHARACTER OF CAPROCK

The character of the caprock of coal No. 6 varies throughout the mine. In general it is a fine-grained, dark gray, argillaceous limestone which usually occurs in medium to thick beds. Its thickness ranges up to a reported maximum of 15 feet. In some parts of the mine the limestone is said to have been 12 to 15 feet thick and devoid of shale partings. In others the limestone is split by shale strata into several beds, the maximum number noted being four. Where measured the total thicknesses of the caprock strata between the top of the uppermost limestone and the base of the lowermost limestone were somewhat less than the reported thickness of the limestone where it occurred as a single thick bed.

The composition of the caprock probably varies from place to place. Where the caprock is composed of alternating shale and limestone strata the series as a unit is likely to have marked lateral variation in chemical composition. In places it may be a woolrock or sub-woolrock, as in the case of the samples mentioned above. Where the caprock is a single thick bed it probably is at least a sub-woolrock in some places.

DEVELOPMENT CONSIDERATIONS

In general the most favorable areas for the exploitation of the caprock limestone are roughly identical with those where coal No. 6 may be stripped, and occur mostly near the line of outcrop of the coal. Areas where the caprock is a single thick bed are considered to be more advantageous for development than the tracts where it is interbedded shale and limestone. Probably the caprock is not everywhere present and coextensive with coal No. 6.

The discussion of the recovery of the caprock during coal stripping operations for the DuQuoin area is equally applicable to the Freeburg area, except that storage piles of the caprock, if composed of mixed limestone and shale, will have to be protected from the weather if it is desirable to prevent disintegration of the shale to a clay.

Much caprock has already been removed in stripping operations and overcast into dump heaps. It is doubtful if this stone can be profitably recovered.

Coal companies have made extensive drillings in the vicinity of Freeburg. The data from these drillings will be valuable in outlining the extent and thickness of the caprock, but other borings should be made in favorable areas to secure samples to determine the chemical composition of the rock and its suitability for making rock wool. Careful prospecting of this nature is desirable because of the variableness of the caprock.

The Illinois Central Railroad connecting St. Louis and Carbondale crosses the area.

Gale-Grand Tower Area

(Alexander, Union, and Jackson counties)

BAILEY LIMESTONE IN MISSISSIPPI RIVER BLUFF BETWEEN GALE AND GRAND TOWER

SUMMARY

Extensive outcrops of a thick, cherty, siliceous limestone formation, comprising all or part of the Mississippi River bluff, occur frequently in two tracts roughly 8 and 14 miles long respectively, separated by an 8-mile strip where the formation is absent from the bluffs. Samples of the limestone have been found to be woolrock. Deposits occur from ½ to 2¼ miles from the Illinois Central and Missouri Pacific railroads. Commercial development of deposits is considered feasible by open pit or sub-surface mining.

INTRODUCTION

The Gale-Grand Tower area (Fig. 5) lies mostly in Union and Alexander counties of southern Illinois and comprises the Mississippi River bluffs and the adjoining uplands from Grand Tower south almost to Gale. The area is divided into two units which are separated by an 8-mile tract not known to contain woolrock. The north tract comprises the Mississippi River bluff and adjoining uplands from the southwest corner sec. 27, T. 10 S., R. 3 W., east of Grand Tower, to the center of sec. 3, T. 12 S., R. 3 W., near Wolf Lake, a distance of about 8 miles. The south tract extends from the center of the

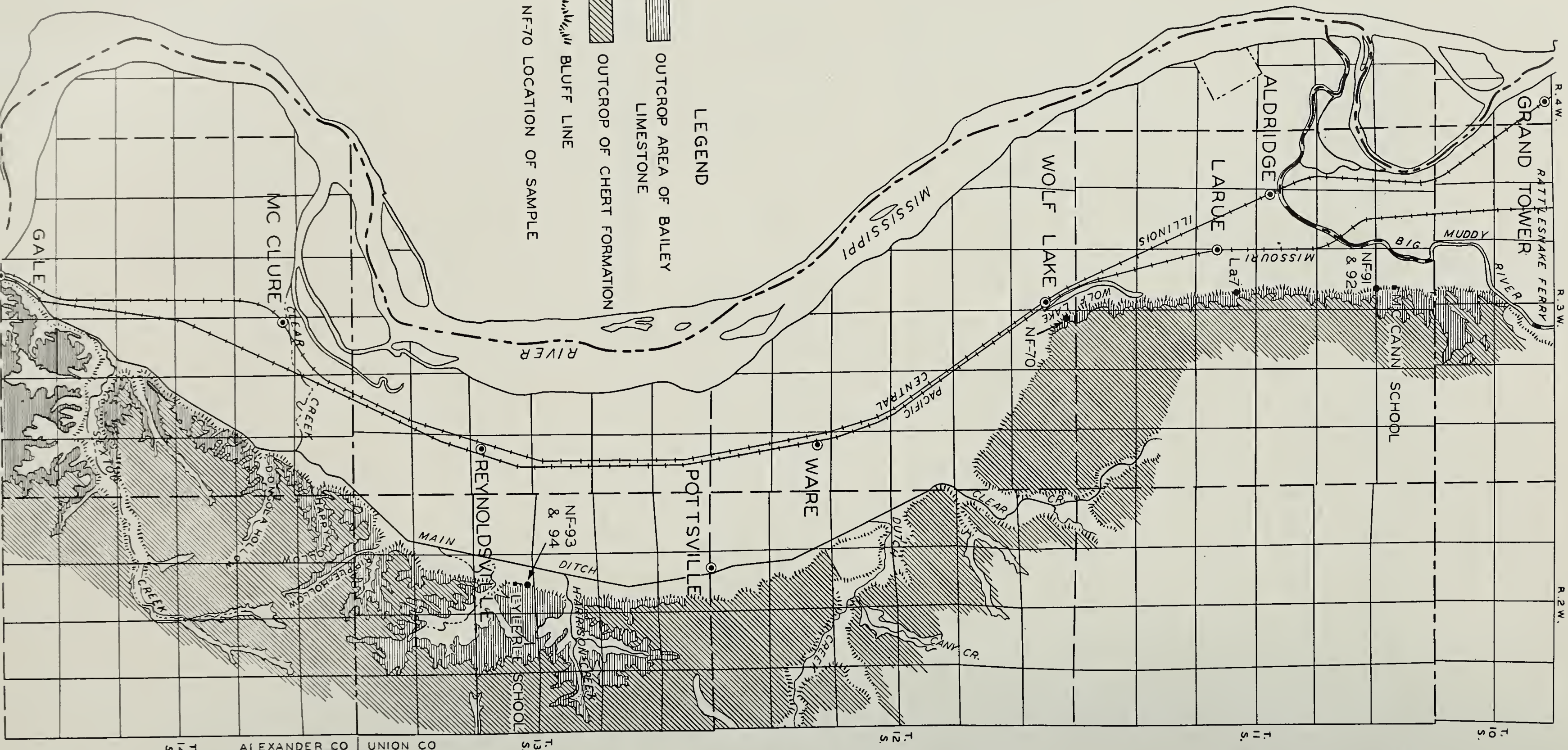


FIG. 5. Map of Gale-Grand Tower area showing distribution of the Bailey limestone and the overlying chert formations and the locations where samples were collected. (Modified from maps of Jonesboro and Alto Pass quadrangles, by T. E. Savage, Illinois State Geol. Survey, unpublished manuscript.)

E. ½ sec. 5, T. 13 S., R. 2 W., near the settlement of Pottsville to the south line of sec. 33, T. 14 S., R. 3 W., near Gale, a distance of 14 miles.

DESCRIPTION OF OUTCROPS[3]

The north tract.—Throughout the north tract 50–100 feet or more of Bailey limestone is exposed almost continuously in the lower portion of the river bluff. The limestone forms sheer lofty cliffs in many places, particularly north of the center of sec. 21, T. 11 S., R. 3 W. An exposure measured in the center of the SW. ¼ SE. ¼ sec. 4, T. 11 S., R. 3 W., near McCann School is as follows:

Geologic section near McCann School

		Thickness *Feet*
Clay, silty, brown (loess)		15–40
Chert, poorly exposed (Grassy Knob formation)		275±
Limestone, cherty, siliceous (Bailey formation)		
c) Exposed (sample *NF-92*)	50	
b) Covered	35	
a) Exposed (sample *NF-91*)	45	
		130+

Another outcrop of Bailey limestone comprising a cliff about 120 feet high, overlain by Grassy Knob chert and loess was measured in the NE. ¼ SW. ¼ NE. ¼ sec. 21, T. 11 S., R. 3 W. (Fig. 6). Sample *La-7* was obtained from the lower 60 feet.

In the bluff northeast of Wolf Lake in the SE. ¼ NW. ¼ NW.¼ sec. 3, T. 12 S., R. 3 W., 60 feet of Bailey limestone is exposed, but above this height loess largely obscures the overlying beds. Sample *NF-70* was taken from this outcrop.

All four samples were found to be woolrocks (Table 1 and pp. 163-165).

The south tract.—At the north end of the south tract the Bailey limestone occurs low in the bluffs and is overlain by 250 feet or more of Clear Creek chert and loess. The limestone rises to the south, however, and between Harrison Creek and an unnamed creek which emerges from the bluff near the center of sec. 20, T. 13 S., R. 2 W., it comprises the bedrock of the entire bluff and upland.

South from the unnamed creek, the limestone is again overlain by Clear Creek chert and loess whose combined thickness ranges from 50 to 200 feet or more locally, as far south as Sexton Creek in the NE. ¼ sec. 27, T. 14 S., R. 3 W. In the vicinity of the mouth of Dongola Hollow in sec. 12, T. 14 S., R. 3 W., Silurian limestone underlies the Bailey limestone and crops out in the lower portion of the bluffs.

---

[3] Data regarding the distribution of the Bailey limestone and associated formations have been obtained largely from geologic maps of the Jonesboro and Alto Pass Quadrangles, by T. E. Savage, in the files of Illinois Geological Survey.

Outcrops of the Bailey limestone are present at intervals in the bluffs throughout the entire tract, but are less common south of Sexton Creek where the limestone occurs high in the bluffs and is mantled with loess. The best

(Photograph by J. E. Lamar)

FIG. 6. A typical cliff outcrop of about 125 feet of Bailey limestone in the NE. ¼ sec. 21, T. 11 S., R. 3 W. Sample *La-7* was taken from the lower 60 feet of this exposure.

bluff exposures occur in the N. ½ sec. 20, and the NE. ¼ sec. 31, T. 13 S., R. 2 W., and between Ripple Hollow in the center of the E. ½ sec. 31, T. 13 S., R. 2 W., and Happy Hollow in the SE. ¼ sec. 1, T. 14 S., R. 3 W.

Two samples were obtained from a 130-foot exposure at the center of the N. ½ N. ½ sec. 20, T. 13 S., R. 2 W., near Lylerle School. Sample *NF-93* was obtained from the lower 30 feet of limestone exposed in a bluff along the road and *NF-94* from the overlying 100 feet of limestone exposed in an adjoining bluff slope. Both samples were found to be woolrock (Table 1 and pp. 163-165).

CHARACTER OF THE BAILEY LIMESTONE

The Bailey limestone is strikingly uniform throughout its area of outcrop in the Mississippi River bluffs. The formation consists of thin beds, ½ inch to 5 inches thick, of fine-grained, brittle, siliceous limestone interbedded with lenticular layers of chert and containing nodules of chert which frequently grade imperceptibly into the limestone. In a few places chert-free limestone a foot to 3 feet thick was observed. The limestone weathers to comparatively small, angular fragments, commonly less than 1½ inches thick. The character of the typical Bailey limestone is shown in figure 7.

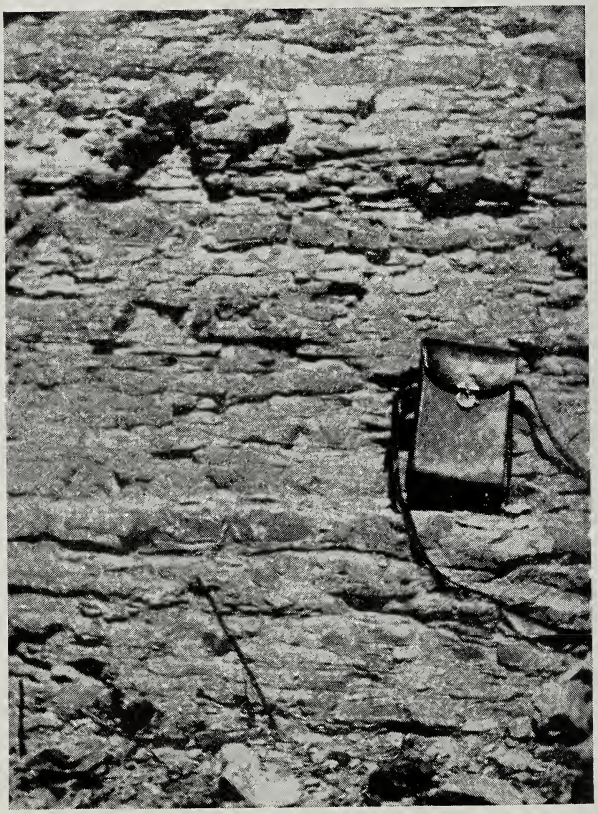
Thickness.—The thickness of the exposed Bailey limestone ranges from a few feet to an observed maximum of 130 feet; exposures of 20–60 feet are common. The total thickness of the formation is not accurately known but is probably between 100 and 150 feet or more. In the north tract probably 80 feet or more of the limestone lies above drainage in most places except northeast of Wolf Lake; here the southward dip of the formation causes a gradual decrease in the exposed thickness as far as the south limit of the tract where the limestone disappears below the level of the Mississippi flood plain.

In the south tract the thickness of the limestone above drainage increases from a few inches at the north end to its full thickness at Harrison Creek. South to Sexton Creek almost the entire thickness of the formation is present. Between this creek and the south limit of the tract the top of the formation is obscured by loess and its thickness is not well known. However, the thickness is probably less than in the adjoining region to the north and is possibly about 50 feet in the higher upland tracts.

Overburden.—The overburden on the Bailey formation is brown, clayey silt, known as loess, and in addition a chert formation throughout much of the area. The loess overlies the bedrock and generally ranges from 15 to 40 feet thick with the greatest thicknesses on the uplands near the bluff. In the north tract the thickness of the chert formation ranges from a few feet to about 275 feet locally. At the outcrop of the Bailey limestone the chert is thinnest but it becomes progressively and rapidly thicker back into the bluff.

In the south tract, chert overlies the Bailey limestone in most places and probably reaches locally a maximum thickness equal to that in the north tract. However, there is no chert formation overlying the limestone in that part of the tract south of Sexton Creek or in the portion lying between two creeks that emerge from the bluffs at the center E. ½ sec. 17, and the center sec. 20, both in T. 13 S., R. 2 W.

The chert overburden, as commonly exposed, is a tumbling mass of blocks and fragments of chert but it is thought to be a solid rock formation back from the weathered outcrop. Where fresh either of the chert formations may be somewhat calcareous in places and may also include beds of cherty lime-



(Photograph by J. E. Lamar)

Fig. 7. Typical Bailey limestone. The thin bedded character of the rock and the chert nodules and layers, which appear darker than the limestone beds, are well shown.

stone. These materials may locally be sub-woolrock in both the north and south tracts and in the region intervening.

DEVELOPMENT CONSIDERATIONS

Mining of the Bailey limestone either by open pit or sub-surface methods appears feasible. Open pit operations will have to deal with a considerable thickness of overburden composed of clayey silt and, except in areas noted above, chert bedrock in addition. The clayey silt is easily handled by mechanical loading devices or may be removed hydraulically. In general, however, it will probably be unprofitable to remove any great thickness of the chert bedrock overburden. Along the top of many of the steep bluffs is an area 100–200 feet wide which is overlain by 15–25 feet of clayey silt and is probably free from consolidated chert overburden though chert gravel may be present locally. Such areas are capable of furnishing large tonnages of rock if exploited by long, narrow quarries paralleling the bluff.

Similar loess and gravel overburden doubtless covers elongate tracts along the walls of valleys tributary to Mississippi River and though in most places striking sheer bluffs are absent, exploration will probably reveal suitable quarry sites in some of these places.

Sub-surface mining is feasible at most places. No particular mining difficulties are expected although in places the rock is jointed and locally it contains small caves or open channels. Proper exploration before developments will indicate where such conditions are prevalent.

From the standpoint of railroad transportation two regions appear most feasible for development. In the north tract the bluff and uplands between the north line sec. 16, T. 11 S., R. 3 W., and Wolf Lake are ½ to ¾ mile from a railroad (Fig. 5). Part of the land between the nearest railroad and the bluffs is low and swampy, being a part of a former course of Big Muddy River. In the NE. ¼ sec. 33, a powder plant occupies the bluff and adjoining flat, and may eliminate a considerable tract from consideration as a region of potential quarry sites. Elsewhere exploration should reveal a number of favorable sites.

The second region comprises the bluffs and uplands north of Gale for about two miles and is within ⅛ to ½ mile of a railroad. The Bailey limestone comprises the highest bedrock and is largely concealed by overlying clayey silt. Quarry sites are probably present but require careful exploration and test drilling to evaluate their possibilities.

The Mississippi River is not close to the east river bluff in the Gale-Grand Tower area, but at the extreme north end of the north tract the Big Muddy River is about ⅛ mile from the bluff and for about 3 miles south is within a mile of the bluff. Quarry sites are available in this region.

RECOMMENDATIONS FOR PROSPECTING

It is recommended that before development is begun, potential quarry sites be prospected by core drilling to determine the thickness of the limestone, the thickness and character of the overburden and, from tests on the cores, the chemical and physical character of the unexposed rock. This information will indicate the most suitable method of quarrying or mining the stone.

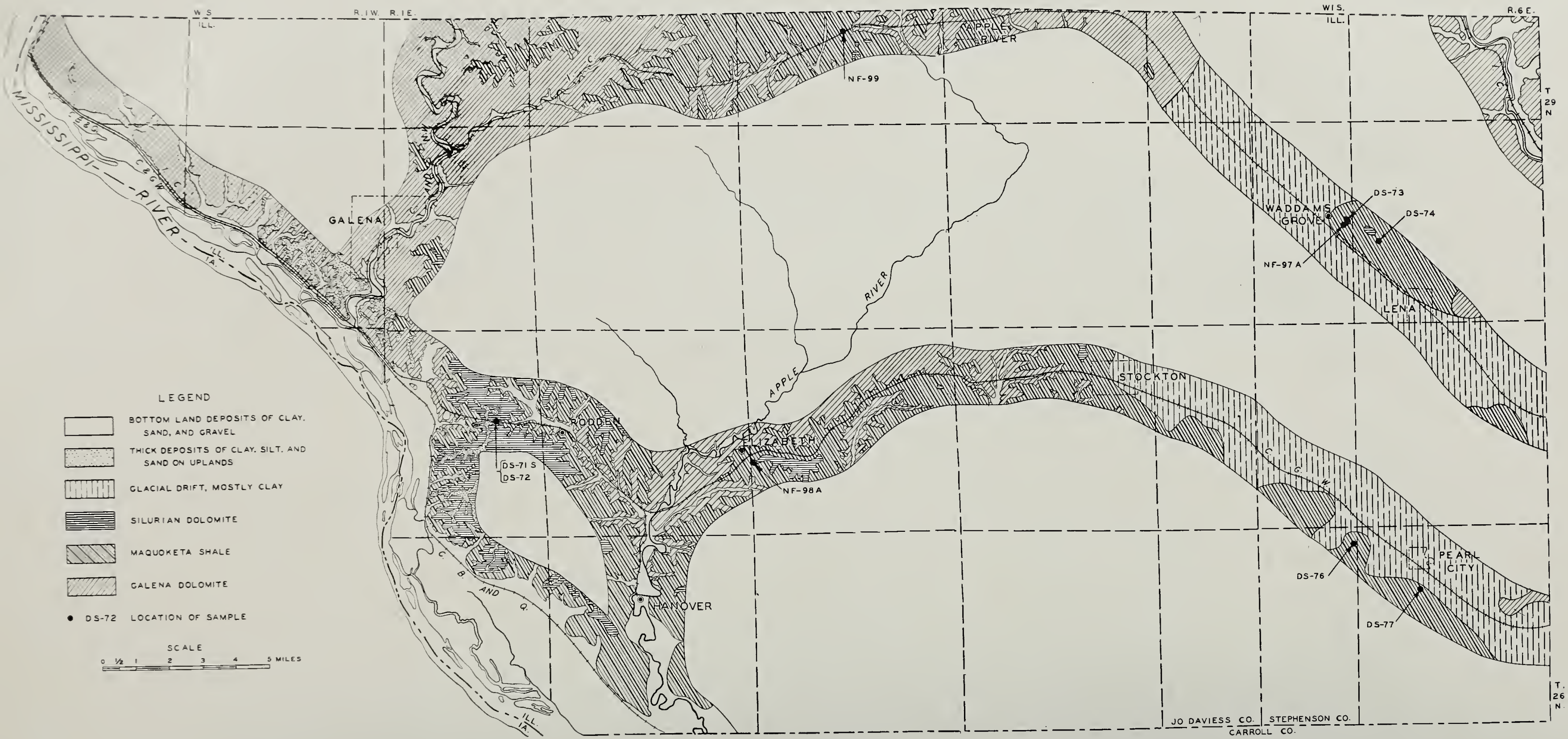


Fig. 8. Map of the JoDaviess-Stephenson County area showing the areal distribution of the major rock formations along railroads. The tract mapped as Galena in the northeast corner of the map also includes the Platteville formation. Thick deposits of clay, silt, and sand are present in places on the uplands along the Mississippi River, thinning eastward. (Modified from Trowbridge, A. C., and Shaw, E. W., Geology and Geography of the Galena and Elizabeth Quadrangles. Illinois State Geol. Survey Bull. 26, Pl. IV, and from unpublished maps, by George E. Ekblaw and R. F. Flint, in files of Illinois State Geol. Survey.)

JoDaviess–Stephenson County Area[4]

SUMMARY

Three bedrock formations, in ascending order, the Galena dolomite, the Maquoketa shale, and the Silurian dolomite, are widespread in the JoDaviess-Stephenson County area (Fig. 8). Some samples of impure dolomite and of interbedded shale and limestone and dolomite from the Maquoketa formation have been found to be woolrock; other samples are sub-woolrock. The very cherty portion of the Silurian formation is also locally a sub-woolrock as is probably the upper, thin bedded phase of the Galena formation. At many places the Maquoketa shale occurs together with either the underlying Galena dolomite or the overlying Silurian dolomite so that mixtures of shale and dolomite for rock wool manufacture can be effected if desirable. Sites for open pit quarries well located with reference to railroad transportation are available at a number of places.

DESCRIPTION OF OUTCROPS SAMPLED

Most of the JoDaviess-Stephenson County area is much dissected by valleys and as a result outcrops of bedrock are numerous. The general distribution of the bedrock formations along railroads is shown in figure 8. More detailed data are given on maps of the scale 1 inch to a mile, in the report on the Galena-Elizabeth quadrangles,[5] which covers most of JoDaviess County.

Samples were obtained for study from typical outcrops in five tracts. They were selected to give data regarding the various types of material available and to serve as a basis for evaluating in a general way the rock wool making possibilities of the numerous other similar outcrops.

WADDAMS GROVE TRACT

Samples of interbedded shale and limestone from the Maquoketa formation obtained from outcrops in a large, gently sloping hill east of Waddams Grove (Fig. 8) have been found to be woolrock and sub-woolrock. The hill is elongated in a northwest-southeast direction and occupies most of the SE. ¼ sec. 13, the N. ½ NE. ¼ sec. 24, both in T. 28 N., R. 5 E., the SW. ¼ sec. 18, and most of the N. ½ of sec. 19, in T. 28 N., R. 6 E. Near the center of the S. ½ SE. ¼ sec. 13, T. 28 N., R. 5 E., the northwest end of the hill is capped by a small tract of Silurian dolomite, which has a probable maximum thickness of about 35 feet; a similar tract of Silurian dolomite caps the hill near the center of the N. ½ sec. 19. The two tracts of dolomite

[4] The term Silurian as used in the description of this area is equivalent to the term Niagaran of earlier reports. Savage (Silurian rocks of Illinois: Bull. Geol. Soc. Am., vol. 37, Dec. 30, 1926, pp. 526-532), has shown that the strata formerly described as Niagaran include both Alexandrian and Niagaran beds. As the areal distribution of these series has not been worked out in detail they are not distinguished in this report.

[5] Trowbridge, A. C., and Shaw, E. W., Geology and geography of the Galena and Elizabeth quadrangles: Illinois State Geol. Survey Bull. 26, 1916, Plate IV.

constitute the highest parts of the hill and are separated by a saddle in the crest of the ridge. The height of the hill varies from about 150 to 200 feet.

The Maquoketa formation is exposed at intervals in the road gutter and in cuts along a northwest-southeast gravel road traversing the hill from a point a little east of the center of the south line of sec. 13, southeast for over a mile to within about one-fourth mile of the southeast corner of sec. 19. It also outcrops for a short distance along a north-south road along the west edge of the NW. ¼ NW. ¼ NW. ¼ sec. 19. The formation is composed largely of thin beds of shale, limy shale, limestone, and dolomite, with the shale and limy shale predominating. The maximum thickness of the formation present in the hill is estimated to be about 150 feet; the average thickness throughout the hill as a whole is about 60 to 70 feet.

Sample *DS-74* was taken from a series of exposures of Maquoketa shale and limestone 35 feet thick in the gutter along the road in the E. ½ sec. 19, T. 28 N., R. 6 E. and was found to be a woolrock (Table 1, p. 61; also pp. 163, 166).

Sample *NF-97A* was also taken from the Maquoketa formation from an outcrop in a road cut near the center of the north line of the NE. ¼ sec. 24, T. 28 N., R. 5 E., where the following section is exposed:

Geologic section near Waddams Grove

		Thickness *Feet*	*Inches*
Silurian formation			
Dolomite, rotted, weathered to loose slabs; possibly talus..		3±	
Maquoketa formation			
Shale, soft, gray........................	Sample *NF-97A*	3	
Limestone or dolomite, brown, rotted, leached	Sample *NF-97A*	1	
Shale, dark gray, limy, poorly bedded....	Sample *NF-97A*	1	2
Limestone, fossiliferous; and shale, gray, limy; both in thin interbedded layers	Sample *NF-97A*	5	
Covered			
Total...		13	2

Sample *NF-97A* was found to be a sub-woolrock requiring the addition of shale, clay, or sandstone to yield a mixture whose chemical composition lies within the composition limits of woolrock. Shale is doubtless available from subjacent beds of the Maquoketa formation.

Sample *DS-73* (Table 1) was taken from a series of exposures of Silurian dolomite aggregating about 30 feet thick in old quarries in the S. ½ SE. ¼ sec. 13, T. 28 N., R. 5 E., and was too high in CO_2 to be a sub-woolrock.

Development considerations.—The overburden on the Maquoketa formation in the Waddams Grove hill is chiefly clay, silt, and soil, together with some rubble from the Silurian dolomite, except in those comparatively small areas on the crest of the hill where a few feet to an estimated maximum of 35 feet of Silurian dolomite caps the Maquoketa formation. The total unconsolidated overburden is estimated to be less than 10 feet thick over a large part of the hill; it is probably thickest on the lower slopes. Open pit quarrying appears to be feasible over a wide area. The Omaha Division of the Illinois Central Railroad runs along the base of the hill on the southwest side.

The exposures of the Maquoketa formation do not permit a thorough evaluation of the rock wool making character of the formation as a whole and it is probable that the proportionate amounts of shale, limestone, and dolomite that comprise the Maquoketa formation vary laterally and vertically throughout the hill. Therefore, thorough prospecting and testing are recommended before development is undertaken.

PEARL CITY TRACT

Impure dolomite and/or calcareous shale of the Maquoketa formation outcrop, or lie at shallow depths locally, in many of the broad hills in the vicinity of Pearl City (Fig. 8).

One deposit of the dolomite phase of the Maquoketa formation was sampled in a small quarry in a conspicuous east-west ridge in the SE. cor. SE. 1/4 sec. 8, T. 26 N., R. 6 E., about a mile south of Pearl City. The strata exposed are as follows:

Geologic section exposed in quarry one mile south of Pearl City

	Thickness *Feet*
4. Soil and disintegrated dolomite	0–4
3. Dolomite, gray to buff, medium grained, in beds about 1 inch thick; cherty bands and thin shale partings present	8
2. Dolomite, same as above but in thicker beds, less cherty	4
1. Dolomite, massive, weathers to thin slabs	14
Covered.	

Sample *DS*-77 (Table 1) was taken from beds 1, 2, and 3, which have a total thickness of 26 feet.

The exposure is located in a broad hill and is about 1/2 mile southwest of the Illinois Central Railroad. Overburden in general is from a few inches to about 10 feet thick and is comprised mostly of clay.

The sample obtained from this outcrop was sub-woolrock which requires the addition of shale, clay or sandstone. Exploration will probably reveal shale underlying the dolomite in this hill; if not, shale may probably be found in other hills in the vicinity (see sample *DS*-76 below; also p. 174).

Twenty-four feet of the calcareous Maquoketa shale is exposed in a road cut on the south side of a large hill at the center of the east line, NE. 1/4 NE. 1/4 SE. 1/4 sec. 1, T. 26 N., R. 5 E., about a mile and one-half west of

Pearl City. Sample *DS-76* (Table 1) was taken from the middle 12 feet of shale. It appears likely that Maquoketa formation comprises the bedrock of the entire hill. The shale is gray, locally iron-stained, in layers 1/16 to ⅛ inch thick, and in places contains thin layers of limestone. Overburden at the outcrop consists of 2 to 4 feet of soil.

Development considerations.—Test drilling will probably reveal large hills of Maquoketa shale and/or dolomite close to transportation near Pearl City. It is possible that the shaly parts of the Maquoketa formation will be locally more calcareous and the dolomite phase locally more argillaceous than the outcrops sampled. Prospecting in regions where these strata are present may reveal deposits of woolrock or adjacent deposits of sub-woolrock which may be used in combination to yield a suitable mixture.

ELIZABETH TRACT

A small quarry in the west end of Terrapin Ridge in the SW. ¼ SW. ¼ sec. 19, T. 27 N., R. 3 E., on the southeast outskirts of the village of Elizabeth (Fig. 8), exposes 25 feet of buff to brown, locally porous, weathered Silurian dolomite in beds 1 to 10 inches thick. The rock contains abundant nodules and beds of chert that range up to 10 inches in thickness. The overburden on the dolomite at the quarry consists of 5 to 10 feet of clayey silt.

Sample *NF-98A* was taken from the exposure in this quarry and results of tests (Table 1) show it to be a sub-woolrock which requires the addition of shale, clay, or sandstone. Shale is available from the Maquoketa formation which underlies the Silurian dolomite and comprises the lower and gentler slopes of Terrapin Ridge.

Development considerations.—Terrapin Ridge is a long, narrow ridge extending eastward from Elizabeth. The Silurian dolomite caps the ridge and underlies an area ⅛ to ½ mile wide, whereas the lower slopes of the hill are comprised of the Maquoketa shale and Galena dolomite.[6] The bedrock is capped by clayey silt which probably reaches the maximum thickness of 10 to 20 feet on the crest of the ridge.

Quarry sites along the north side of the ridge would have available only a narrow tract of stone because a paved highway follows the crest of the ridge close to the steep north slope. More extensive tracts are available along some of the lateral ridges extending south from the main crest of the ridge, especially in the N. ½ sec. 29, T. 27 N., R. 3 E. The Chicago Great Western Railroad runs along the north side of the ridge.

As the Maquoketa formation is known to contain woolrock in some places, it may also include woolrock in the Elizabeth tract. Prospecting should be directed so as to evaluate the relative merits of exploiting any woolrock beds which may be found in the Maquoketa formation as against the alternative procedure of combining Maquoketa shale and Silurian or Galena dolomite.

[6] Trowbridge, and Shaw, Idem, Plate IV.

RODDEN TRACT

Silurian dolomite and the subjacent Maquoketa shale are exposed for a distance of about 350 feet in the cut at the eastern portal of the Chicago Great Western Railroad tunnel in the NW. ¼ SE. ¼ sec. 14, T. 27 N., R. 1 E., JoDaviess County, about two miles west of Rodden (Fig. 8). The outcrop occurs in the lower slopes of a large hill which is more or less typical of other similar hills in the vicinity, in that it is composed of Maquoketa shale in the lower portion and is capped with Silurian dolomite. The following beds are exposed:

	Thickness Feet	Inches
7. Silt, clayey, brown	0–20±	
Silurian formation		
6. Dolomite, gray, thin bedded, slightly argillaceous	18	
5. Dolomite, hard, fine-grained	2	
4. Dolomite, argillaceous, soft, breaks into angular fragments	6	
3. Sandstone, brown, coarse		4
Maquoketa formation		
2. Shale, black, thin bedded, with 3 limestone lenses 2 inches to 3 feet thick	20	
1. Shale, black, greenish at base, locally limy layers 1 to 2 inches thick	20	
Covered (5 feet to level of railroad track)		

Sample *DS-71S* was taken from beds 1 and 2 and *DS-72* from beds 4, 5, and 6.

Analyses of these samples show them both to be sub-woolrocks, but of such composition that their mutual combination in the proper proportions would yield a mixture whose chemical composition lies within the composition limits of woolrock.

Development considerations.—The Silurian strata exposed are a part of the lower thin bedded member of that formation (p. 48) which is about 80 feet thick at this place.[7] As this part of the Silurian formation is shaly or argillaceous in many places, prospecting may reveal additional strata of sub-woolrock overlying the exposed beds. The Silurian strata above the lower thin bedded member are massive and are probably comparatively pure. The beds of the Silurian formation which were sampled could probably be developed extensively only by subsurface mining because of heavy overburden but prospecting of overlying beds may show sufficient additional sub-woolrock to make open pit quarrying possible. In view of the fact that the two formations exposed in the cut are dominantly shale or dolomite, the tract also offers opportunities for the development of mixtures. The type of mining best suited to the exploitation of this deposit will depend on the results of detailed

[7] Trowbridge, A. C., and Shaw, E. W., Geology and geography of Galena-Elizabeth quadrangles: Illinois State Geol. Survey Bull. 26, p. 75, 1916.

prospecting. Thorough testing and prospecting is recommended before development is undertaken.

APPLE RIVER TRACT

A cut 300 to 400 feet long along the Illinois Central Railroad in the SW. ¼ NW. ¼ NW. ¼ sec. 22, T. 29 N., R. 3 E., about 3 miles west of Apple River (Fig. 8) exposes 20 feet of very impure Maquoketa dolomite. The rock is gray and occurs in beds 4 to 10 inches thick. The upper 15 feet is comparatively thick bedded and is cut by fractures which divide it into angular blocks. The lower 5 feet is shaly. One 5-inch bed of relatively pure dolomite was noted near the base of the cut. The overburden is 3 to 5 feet of clayey silt.

Sample *NF-99,* taken from the rock exposed in the cut, is a woolrock (Table 1 and pp. 164, 167).

Development considerations.—The railroad cut where the above exposure was noted occurs in a saddle between two large hills whose crests lie roughly ⅛ mile northwest and ¼ south respectively. These hills probably contain rock similar to that sampled and also overlying beds whose character is not known. Along the lower slopes of the hills below the level of the railroad cut occur other unexposed strata which are also part of the Maquoketa formation. The Galena dolomite probably underlies the valley on the east side of the saddle eastward from a point in the W. ½ NE. ¼ NW. ¼ sec. 22.

Core drilling and testing of samples are necessary to evaluate the commercial possibilities of this tract. It is thought that the tract offers promise for the occurrence of woolrock deposits of commercial size, suitable for open pit quarrying.

GENERAL CHARACTER OF FORMATIONS IN THE JO DAVIESS-STEPHENSON COUNTY AREA[8]

INTRODUCTION

The three formations present in the JoDaviess-Stephenson County area which offer promise as sources of rock wool making material are, in order from oldest to youngest, the Galena dolomite, the Maquoketa formation, mostly shale, and the Silurian dolomite. So far as is known, the dolomite formations will require the addition of shale or sandstone in order to yield a mixture whose chemical composition lies within the composition limits of woolrock. Shale is available in most places from contiguous parts of the Maquoketa formation. The Maquoketa formation, though dominantly shale, locally includes beds of woolrock as well as sub-woolrock. The following dis-

[8] The data upon which this discussion is based, including the geologic sections presented, have been obtained largely from the following reports:
(1)—Trowbridge, A. C., and Shaw, E. W., Geology and geography of the Galena-Elizabeth quadrangles: Illinois State Geol. Survey Bull. 26, 1916.
(2)—Trowbridge, A. C., and Shaw, E. W., Geologic Atlas of the U. S., U. S. Geol. Survey, Galena-Elizabeth folio (No. 200), 1916.

cussion, therefore, deals chiefly with the Maquoketa formation and the adjacent parts of the Galena and Silurian dolomites.

GALENA DOLOMITE

The general distribution of the Galena dolomite in areas bordering railroads is shown in figure 8. The formation is mostly a crystalline dolomite, usually porous, which weathers with an irregular surface. The lithologic characteristics of the formation, except in the extreme upper and lower parts, are reasonably consistent throughout the area. A generalized section of the formation follows:

Generalized section of the Galena formation[9]

	Thickness *Feet*
Upper thin bedded member: thin beds of dolomite, separated by calcareous and shaly partings; beds thick in the lower part and thinner near the top; fossiliferous	30
Upper, massive, non-cherty member: coarse-grained, massive dolomite	70
Massive, cherty member: coarse-grained, porous, thick-bedded dolomite containing nodules and layers of chert	100
Lower, massive, non-cherty member: dolomite beds averaging 4 to 5 feet in thickness; grades into thin beds below	20–30
Oil-rock member: thin-bedded limestone containing irregular lenses of oil-rock; highly fossiliferous	13–25
	240–245

The upper 30 feet of the Galena formation appears to offer the most promise for the occurrence of woolrock. It is further favored by being overlain at many places by the Maquoketa formation from which shale may be secured for mixing with the dolomite if necessary and feasible. The upper Galena is composed of limestone or dolomite beds, 2 inches to 2 feet thick, interbedded with calcareous shaly partings 2 to 12 inches thick. The thicker limestone or dolomite beds are hard, crystalline, buff, and usually porous. The shaly upper Galena is not everywhere present; it is said to be particularly prevalent in the general vicinity of Scales Mound. The upper Galena is probably a sub-woolrock in some places.

Characteristic outcrops are reported at the following places:

Town of Apple River; small quarries at northwest corner of town, along the railroad, and along roads east and south of town.

Town of Apple River; several exposures in cuts along Illinois Central Railroad within 3 miles of town.

Town of Rodden; outcrop along Chicago Great Western Railroad.

Town of Hanover; outcrop below dam across Apple River.

[9] Trowbridge and Shaw, Op. cit. (No. 1), pp. 51 and 52.

One and a half miles west of Stockton; 8 feet of upper Galena in cut along Chicago Great Western Railroad.

Town of Scales Mound; exposure along Illinois Central Railroad ⅓ mile west of town.

Parts of the massive cherty member near the middle of the Galena formation may possibly contain sufficient chert locally to be a sub-woolrock or woolrock.

MAQUOKETA FORMATION

The Maquoketa formation, though extensively present in the JoDaviess-Stephenson County area (Fig. 8), is not as frequently or as well exposed as the over and underlying formations because it gives rise to gentle slopes and a soil cover. It is highly variable, comprised of about 80 per cent shale and the remainder comparatively pure, sandy or shaly limestone or dolomite. Its full thickness ranges from about 110 to 210 feet and variations result mostly from the fact that the upper surface of the formation is uneven. Certain general lithologic subdivisions apply to many outcrops but no universally characteristic subdivisions appear to be definable because of the formation's variability. It is suggested that the following three-fold division is applicable in a very general way:[10]

3. At the top a zone of massive, heavy beds of limestone, interbedded with shale; not present everywhere.
2. A middle zone of shale with sandy and calcareous layers interbedded; thickness variable.
1. At the bottom, a blue-black shale, with a few lenses of sandy limestone; thickness variable.

Outcrops of the upper Maquoketa in the Waddams Grove, Rodden, Pearl City, and Apple River tracts have been described. General geologic sections of the formation exposed in other parts of the area are given below.

Geologic section of Maquoketa shale near Galena[11]

	Thickness *Feet*
Clay shale interbedded with thin layers of limestone and dolomite, most of which are compact, though some contain lenses of coarse fossiliferous limestone. This member has been removed by pre-Silurian and post-Paleozoic erosion from all but very small areas near Galena	60
Clay shale, soft, blue, nonfossiliferous, mostly rather massive but in places finely laminated and darker and harder than elsewhere; also contains local lenses of limestone and dolomite	95
Clay shale, with a 6- to 12-inch layer of unconsolidated material of sandy texture, loose fossils, considerable iron oxide, and particles and pellets of variable composition	2
	157

[10] Trowbridge and Shaw, Op. cit. (No. 1), p. 62.
[11] Trowbridge and Shaw, Op. cit. (No. 2), p. 5.

Geologic section of Maquoketa shale in the southwest corner of the Galena quadrangle (probably near Blanding)[12]

	Thickness Feet
Shale, soft, blue or grayish-blue, nonfossiliferous, weathering into irregular small blocks	50
Dolomite, discontinuous bed, very fossiliferous	1
Shale, blue, soft, with earthy dolomite lenses in some places	45
Shale, soft, sandy, with pellets of phosphate and a few fossils	1
	97

Geologic section of Maquoketa shale exposed near Elizabeth[13]

	Thickness Feet
Clay shale, with thick, coarse grained, fossiliferous limestone layers. (This member is not found at a few places north of Elizabeth)	35
Limestone, thin, somewhat magnesian; contains some chert and a few fossils; includes in places some shale, but is generally resistant, making benches on valley sides, like those 3 miles southeast of Elizabeth	40
Clay, weathering yellow, fossiliferous	10
Shale, hard, bluish, poorly exposed	10
Shale and argillaceous dolomite alternating, nonfossiliferous	30
Mostly concealed, but small exposures indicate soft blue shale	50
Unconsolidated ferruginous and fossiliferous bed (thin or absent at a place east of Schappville)	3
	178

Geologic section of Maquoketa shale exposed near Scales Mound[14]

	Thickness Feet	Inches
Clay shale, with several beds of coarse-grained, fossiliferous limestone and other fossiliferous layers, also fine-grained compact dolomite. (These beds absent except northeast of Scales Mound)	70	
Clay shale alternating with thin beds of compact earthy dolomite	25	
Clay shale, soft, with a few lenses of magnesian limestone	25	
Clay shale alternating with compact brittle dolomite in beds 1 to 12 inches thick	20	
Clay shale, soft, blue	10	
Clay shale with a few thin beds of compact, fine-grained dolomite	10	
Clay shale, bluish gray, soft, containing a few hard concretionary ? bodies	33	

[12] Trowbridge and Shaw, Op. cit. (No. 2), p. 5.
[13] Trowbridge and Shaw, Op. cit. (No. 2), p. 5.
[14] Trowbridge and Shaw, Op. cit. (No. 2), p. 5.

Geologic section of Maquoketa shale exposed near Scales Mound—Concluded

	Thickness Feet	Thickness Inches
Clay shale, reddish, with fossils at base	3	
Unconsolidated, ferruginous, fossiliferous bed having a sandy texture		11
Clay shale, soft, gray	3	9
Unconsolidated ferruginous fossiliferous bed having a sandy texture and containing loose particles and pellets of indefinite composition		6
	201	2

Exploration and testing will probably reveal many places where the interbedded shales and calcareous shales and limestones and dolomites of the Maquoketa formation may be quarried by open pit methods and will have the chemical composition of sub-woolrock or woolrock. In general the upper two divisions of the formation appear to offer more promise of containing suitable deposits than the lower division. The thicker beds of very argillaceous dolomite or limestone, such as that exposed in the Apple River tract, probably deserve particular attention because they possess many of the properties of material now commercially employed for making rock wool.

SILURIAN DOLOMITE

The Silurian dolomite, the youngest bedrock formation exposed in the JoDaviess-Stephenson County area, occurs primarily as a capping of sinuous narrow ridges (Fig. 8). Though widely distributed, it is not as extensive as the Galena or Maquoketa formations. Due to the fact that the base of the formation is uneven and the upper surface irregular as a result of erosion, the thickness of the Silurian varies notably. In places it is but a few feet thick, but where well developed the thickness usually ranges from 100 to 150 feet. About 3 miles southwest of Rodden 250 feet of the formation is present locally.

Where the Maquoketa formation is thinner than usual, the depressions in its surface are filled with Silurian sediments of variable character. They are usually thin bedded, often argillaceous, locally cherty, particularly in the upper part of the succession, and at some places include thin beds of calcareous or sandy shale. The argillaceous phase of the thin bedded member of the Silurian is exposed in the Rodden area and the cherty phase in the Elizabeth area. Thicknesses of 80 to 90 feet of the thin bedded member are recorded locally.

Above the thin bedded portion, the Silurian is characteristically a massive, locally cherty dolomite in beds 5 to 10 feet thick. It is usually a comparatively pure dolomite where not cherty. The rock outcrops at many places, generally in cliffs or ledges.

The following generalized sections show the lithologic character of the Silurian formation in parts of the area where it is well developed.

Geologic section of Silurian dolomite exposed in southwest corner of Galena quadrangle[15] *(probably near Blanding)*

	Thickness Feet
Dolomite, thick bedded, gray, fossiliferous	160
Dolomite, thin bedded, very cherty	10
Dolomite, hard, massive, grayish, in thick layers, in places cherty, contains a few fossils	30
Dolomite, earthy, a few fossils	16
Dolomite, bluish, weathers shaly	9
Dolomite, earthy, bluish where fresh, weathering brown or buff and finally to a sandy clay; contains some chert and a few indistinct fossils	23
Dolomite, earthy, weathering into thin chips	5
Dolomite, laminated, yellowish, sandy	1+
	254+

Geologic section of Silurian dolomite exposed about Hanover[16]

	Thickness Feet	Inches
Dolomite, cherty, thin bedded; beds 6 to 12 inches thick; chert in layers and lenses 1 to 6 inches thick; one-fourth of material is chert	20	
Dolomite, thin beds, weathering to several beds to the inch; yellow, soft, earthy, with shale partings	7	
Dolomite, thin beds, hard, white, containing much chert in irregular nodules; nonfossiliferous	12	
Dolomite, soft, yellowish, argillaceous, earthy with shaly partings and dendritic markings; no chert, and nonfossiliferous	16	
Concealed	7	
Dolomite, hard, yellow, thin bedded, nonfossiliferous	3	
Dolomite, yellow, earthy, sandy		4
Dolomite, hard, blue, nonfossiliferous	1	3
	66	7

Samples of the argillaceous dolomite and cherty dolomite of the thin bedded phase of the Silurian formation have been found to be sub-woolrocks in the Rodden and Elizabeth tracts; elsewhere it will probably be found to be similar. Locally woolrock may be present. Because of the variability of

[15] Trowbridge and Shaw, Op. cit. (No. 2), p. 6.
[16] Trowbridge and Shaw, Op. cit. (No. 2), p. 6.

the beds, thorough prospecting and testing is recommended before development is undertaken.

GENERAL DEVELOPMENT CONSIDERATIONS

Open pit quarrying of woolrock or sub-woolrock is probably feasible at many places in the uplands of the JoDaviess-Stephenson County area unless operations are confined to a thin bed, when sub-surface mining may be necessary. In general the bedrock strata dip southwest or south at a rate of about 25 feet per mile, though locally dips as low as 15 feet and as high as 50 feet per mile are common. Unconsolidated overburden consists of brown or yellow clayey silt, known as loess, and locally of material residual from the weathering of the bedrock. In the eastern part of the area pebbly glacial clay is also present on the bedrock (Fig. 8).

The loess is thickest near the bluffs of Mississippi River and commonly reaches thicknesses of 30 to 40 feet. Inland from the bluff the loess thins gradually eastward and is generally 5 to 15 feet thick. The residual materials consist of clay, gravel, and soil and locally reach a thickness of 18 feet. The glacial clay is thickest in the valleys of the eastern part of the area. Those regions where glacial clay hides the bedrock are so indicated in figure 8. On the hills and ridges the thickness is probably not great in most places.

Prospecting by drilling and testing of the samples is recommended in order to ascertain the detailed character of deposits, the nature of the rock where unweathered, and the most feasible procedure for development.

LaSalle Area

LASALLE LIMESTONE IN THE VICINITY OF LASALLE

SUMMARY

A "Coal Measures" limestone, the LaSalle limestone, occurs in places in the vicinity of LaSalle in one or the other of two phases, the "gray" and the "buff." The gray phase, which is extensively quarried for making Portland cement, is usually a sub-woolrock. Samples of the buff phase show that it is commonly a sub-woolrock but locally a woolrock. Shale is available from underlying and locally overlying beds for mixing with the sub-woolrocks if desirable. Deposits capable of exploitation are present.

INTRODUCTION

The LaSalle limestone of "Coal Measures" age crops out at a number of places in the vicinity of the city of LaSalle (Fig. 9). At and east of LaSalle the formation is a gray cement rock and is extensively used for the manufacture of Portland cement. It is usually a sub-woolrock. West of LaSalle the formation weathers to a buff color and also differs from the cement rock phase in that it is generally higher in magnesia, silica, and alumina and iron oxide. It is commonly a sub-woolrock and locally a woolrock. The buff and gray phases are separated by a zone one-half mile or less wide in which the character of the limestone is transitional. Because of the differences between the two phases their distribution and rock wool making properties are discussed separately.

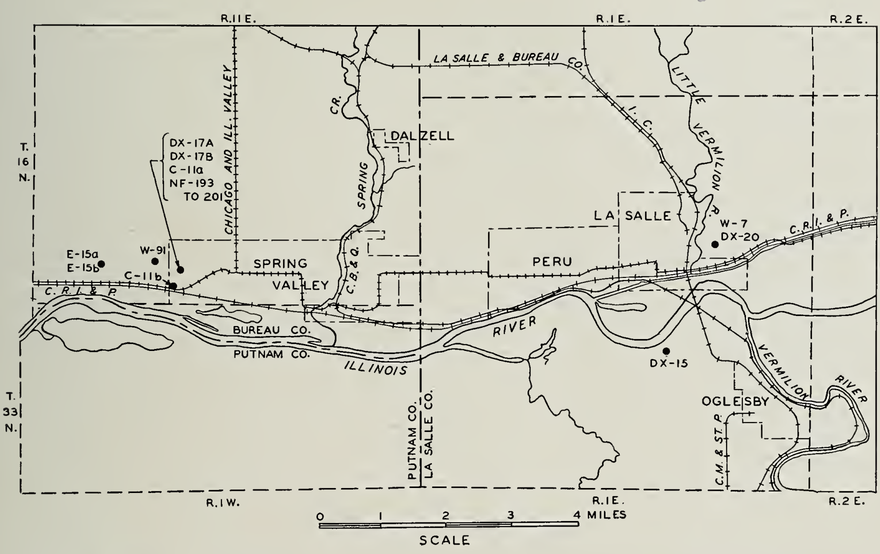


FIG. 9. Map of LaSalle area showing locations where samples were taken.

BUFF PHASE OF LASALLE LIMESTONE

DESCRIPTION OF OUTCROPS

The buff phase of the LaSalle limestone outcrops only in the bluffs and ravines tributary to Illinois Valley between the west edge of LaSalle and the village of Marquette, 8 miles to the west. Outcrops are abundant in both the north and south bluffs and well records indicate that the stone extends below the uplands some distance back from the bluffs.

The typical buff stone has been sampled from several outcrops. At an outcrop in a small gully along the west side of a mine dump at the west edge of the town of Spring Valley in the NE. 1/4 NW. 1/4 SW. 1/4 sec. 33, T. 16 N., R. 11 E., the following section was exposed:

Geologic section at Spring Valley

		Thickness Feet	Inches
12.	Clay and soil	10±	
11.	Limestone (LaSalle), dense, light gray, weathering to buff, in beds 1 to 18 inches thick; shale partings up to 6 inches thick between most of the limestone beds. (Samples *DX-17A*, *DX-17B*, and *C-11a*)	10–12	
10.	Shale, light and dark gray. (Sample *NF-201*)	5	1
9.	Limestone, dark gray, weathers brown. (Sample *NF-200*)	1	3
8.	Shale, gray, dark gray and black. (Sample *NF-199*)	6	9
7.	Coal	0	4
6.	Clay, gray, dark gray and black. (Sample *NF-198*)	8	5
5.	Limestone, dense, gray, nodular, weathers buff; in slabby, lenticular beds, having shale partings up to 6 inches thick. (Sample *NF-197*)	4	0
4.	Shale, greenish-gray, thick bedded, with numerous calcareous nodules. (Sample *NF-196*)	7	6
3.	Limestone, gray, greenish or reddish; grades laterally into shale containing limestone nodules. (Sample *NF-195*)	3	3
2.	Shale, gray, dark gray and black; lower 5 feet contains calcareous nodules. (Sample *NF-194*)	9	9
1.	Limestone, dark gray, in small nodules closely spaced in light yellow clay. (Sample *NF-193*)	2	0
	Covered		

Samples *DX-17A, DX-17B,* and *C-11a*[17] of the buff LaSalle limestone were found to be woolrocks, as were samples *NF-193, 195,* and *197* of the subadjacent beds. Samples *NF-196* and *200* were sub-woolrocks (Table 1, pp. 62, 63; also pp. 163, 165). None of the beds below the LaSalle limestone are considered thick enough to be individually workable but may be found useful for mixing with the limestone if its composition requires modification for making rock wool. Calculations based on CO_2 content indicate that a combination of the samples from beds 9 and 10 with Sample *C-11a* from bed 11, the LaSalle limestone, would yield a mixture whose chemical composition lies within the composition limits of woolrock. Addition of the samples from any of the subjacent beds consecutively as, for example, beds 5, 6 and 8, yields on the same basis a mixture whose composition places it among the sub-woolrocks.

Sample *W-91* was collected from an outcrop of 11 feet of the buff stone in the NW. 1/4 SE. 1/4 NE. 1/4 sec. 32, T. 16 N., R. 11 E., about a half mile west of the locality described above. The underlying beds were similar in character and thickness to the equivalent beds at Spring Valley. The analysis of the sample (Table 1) indicates the stone to be a sub-woolrock.

[17] Bleininger, A. V., Lines, E. F., and Layman, F. E., Portland Cement Resources of Illinois, Illinois State Geol. Survey Bull. 17, 1912, pp. 80 and 97.

A short distance southwest of the outcrop described at Spring Valley sample *C-11b* was secured from an 8-foot outcrop of the buff limestone in the SW. 1/4 NW. 1/4 SW. 1/4 sec. 33, T. 16 N., R. 11 E.[18] Its chemical analysis (Table 1) shows it to be a sub-woolrock.

Sample *E-15a* was taken from a 7½-foot outcrop of the buff stone in a ravine east of Marquette in the NW. 1/4 SW. 1/4 NW. 1/4 sec. 32, T. 16 N., R. 11 E.[19] Its chemical analysis (Table 1) shows it to be a sub-woolrock. An analysis of a sample from 7 feet of the shale underlying the limestone, sample *E-15b*[20] is given in Table 1.

Another outcrop in a road cut at the south end of the LaSalle bridge in SW. 1/4 SE. 1/4 SE. 1/4 sec. 22, T. 33 N., R. 1 E., showed 8 feet of light buff or gray limestone in beds 6 inches to 3 feet thick and was the source of sample *DX-15*. This stone is transitional between the gray and brown phases and the analysis indicates it is a comparatively pure limestone (Table 1).

DEVELOPMENT CONSIDERATIONS

North bluff Illinois River.—The buff LaSalle limestone outcrops at many places in the north bluff of Illinois River and its tributary valleys and generally occurs at the top of the bedrock immediately underlying unconsolidated clay and gravel deposits. The limestone is absent only where eroded along Spring Creek and in a few areas where deep channels were cut in the bedrock before the accumulation of the clay and gravel deposits which now fill them.

The maximum thickness of stone observed in outcrops was 12 feet in the gully west of Spring Valley, previously discussed. Eleven feet of stone outcrops in the next ravine to the west, and 9 feet occurs in the first ravine east of the village of Marquette.

The best known area for open pit development lies between the two gullies in the NW. 1/4 SE. 1/4 sec. 32, and NW. 1/4 SW. 1/4 sec. 33, T. 16 N., R. 11 E., west of Spring Valley. The overburden on the limestone in this tract consists of gravel and sand locally and elsewhere of pebbly clay. Near the bluffs and the ravines the overburden is less than 10 feet thick but it gradually increases in thickness away from them. An area of 20-40 acres is probably present in the southeast part of this tract with an overburden averaging less than 20 feet in thickness. However, thorough core drilling and testing of samples are recommended to evaluate probable variations in the character and thickness of the LaSalle limestone and of the overburden.

Samples of the buff limestone show that it is frequently a sub-woolrock requiring the addition of shale or sandstone. Other samples which are woolrock have CO_2 contents close to the upper limit for woolrock and can also

[18] Idem, pp. 80 and 97.
[19] Idem, pp. 80 and 97.
[20] Idem, pp. 80 and 104.

probably be benefited by the addition of shale or sandstone. Shale is available from underlying beds. No sandstone strata are known close at hand but silica sand is available from pits at Ottawa, and "Coal Measures" sandstone at Coal Hollow about 7 miles northwest of Spring Valley.

It is possible that some of the strata underlying the limestone (p. 52) could be included with the limestone to form a mixture for making rock wool, thereby increasing the thickness of quarryable rock and the amount of raw material available per acre. The feasibility of this plan depends on the development of proper equipment for commercially melting mixtures of this nature at a low cost.

The foot of the north bluff is traversed by the Chicago, Rock Island and Pacific Railroad throughout the area, the Chicago and Illinois Valley Railroad from Spring Valley west, and the Chicago, Burlington and Quincy Railroad from Spring Valley to LaSalle.

South bluff Illinois River.—The buff phase of the LaSalle limestone crops out at many places in the south bluff and tributary valleys of Illinois River from the south end of the highway bridge at LaSalle west to sec. 30, T. 33 N., R. 1 W., near the big bend in the valley. In the eastern mile and a half of this area the limestone is only about 6 feet thick and is overlain by interbedded shales and limestones. In the remainder of the area it occurs at the top of the bedrock immediately underlying the unconsolidated glacial clay and gravel. Considerable variations in thickness of the stone result from erosion of the upper surface before the glacial materials were deposited. Locally the stone has been completely eroded. It is 4 feet thick near the center of the SW. ¼ sec. 28, T. 33 N., R. 1 E., 11 feet thick in the NE. ¼ SE. ¼ sec. 26, 15 feet thick in the NW. ¼ NE. ¼ sec. 29, and 12 feet thick in the SE. ¼ NW. ¼ NE. ¼ sec. 30, all in T. 33 N., R. 1 W. Almost everywhere the stone is overlain by 40 to 60 feet of unconsolidated overburden. No large tracts for open pit mining are known and the feasibility of subsurface mining is questionable. There is no railroad along the south bluff but locally the bluff is ⅛ to ¼ mile from Illinois River.

GRAY PHASE OF LASALLE LIMESTONE

The gray phase of the LaSalle limestone outcrops in an area about 2 miles wide and 10 miles long, extending northwest-southeast along the Vermilion and Little Vermilion rivers. It is well exposed in the quarry of the Alpha Portland Cement Company at LaSalle and the quarries of the Marquette and Lehigh Portland Cement companies at Oglesby. A generalized section of the typical LaSalle limestone is as follows:

Generalized section of gray phase of LaSalle limestone[21]

		Thickness Feet
5.	Limestone, very pure, semi-crystalline, gray; weathering to brownish or reddish color, 5 to 9 feet	6
4.	Shale, gray; often entirely absent or incorporated in the underlying bed	2
3.	Limestone, compact and heavy bedded where fresh but develops thin beds where weathered. A two-foot bed at the base is relatively constant over the entire area as a pure semi-crystalline gray limestone	12
2.	Limestone or shale; south of the Illinois commonly argillaceous, thin bedded limestone; north of the Illinois more argillaceous to nearly a shale, 6 to 8 feet	7
1.	Limestone, hard, gray, crinoidal; over large areas about 1 foot thick, but near Vermilion rivers as thick as 6 feet	2

Sample *DX-20* was obtained from the limestone exposed in the SW. corner of the Alpha Portland Cement Company quarry in the SE. ¼ NW. ¼ sec. 14, T. 33 N., R. 1 E. Analysis of the sample (Table 1) shows it to be a sub-woolrock.

The average of 14 analyses, obtained from various sources, of the gray phase of the LaSalle limestone is as follows:

$CaCO_3$	83.51
(CaO)	46.81
$MgCO_3$	2.36
(MgO)	1.13
Al_2O_3 / Fe_2O_3	4.80
SiO_2	7.71

Both the analysis of *DX-20* and the average analysis given above show that the limestone requires the addition of shale, clay, or sandstone (p. 174). An analysis of the shale overlying the limestone in the quarry of the Alpha Portland Cement Company is given in Table 1 (p. 63), sample *W-7*.

DEVELOPMENT CONSIDERATIONS

The gray phase of the LaSalle limestone has been extensively quarried and it is possible that much of the rock close to railroad transportation and capable of open pit exploitation is owned or under lease by the cement companies. The limestone crops out[22] along the west side of Vermilion River from near the center of sec. 6, T. 32 N., R. 2 E., to the river's mouth and along the east side downstream for about 2½ miles below the center of sec. 6 and from a point in the center NW. ¼ sec. 30, T. 33 N., R. 2 E., downstream

[21] Cady, G. H., Geology and Mineral Resources of the Hennepin and LaSalle quadrangles; Illinois State Geol. Survey Bull. 37, 1919, p. 67.
[22] Cady, G. H., Op. cit., Plate II.

to the bluffs of Illinois River. It is also present in the south bluff of Illinois River from Vermilion River both east and west for about a mile.

On the north side of Illinois River the LaSalle limestone occurs in the west bluff of Little Vermilion River from LaSalle north to sec. 28, T. 34 N., R. 1 E., with the exception of about a mile northwest from the south line of sec. 2, T. 33 N., R. 1 E. The bed outcrops in the east bluff along the lower two miles of the stream's valley. It also outcrops in Illinois River bluffs for about a mile east from the mouth of Little Vermilion River and about a half mile west.

Only one sizeable area of stone, not being exploited, with less than 35 feet of overburden is known. This occurs in the central part of sec. 34, T. 34 N., R. 1 E., a mile from the Illinois Central Railroad. Exploration may reveal tracts that can be mined by subsurface methods and that are close to railroad transportation in the S. ½ sec. 24, T. 33 N., R. 1 E. and in the west ½ sec. 11 of the same township.

Shale for addition to the limestone is available from the red and gray shales which overlie the limestone or from the gray shale underlying it. Sandstone, if desired, is available from either "Coal Measures" beds or the St. Peter formation at a number of nearby places, and silica sand may be obtained from pits near Ottawa. Prospecting of deposits by drilling and testing of samples is recommended before development is undertaken.

TABLE 1—*Chemical analyses of bedrock materials in economically favorable areas (a)*

Area	Sample No.	Formation	Material	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	MgO	CaO	CO_2	H_2O-	Loss on ignition 110-°400°C.	Loss on ignition 400°-1000°C.	Loss on ignition	Other constituents
Blue Island P. 65	Composite A-1 to A-10	Niagaran....	Sub-woolrock..	16.8	4.2	1.8	.....	16.7	23.7	35.7	0.05	......	......	36.3	SO_3 (soluble)-0.0, S (total) -0.2
	Composite A-11 to A-19	Niagaran....	Woolrock......	37.1	9.0	2.2	.....	10.9	14.3	21.2	0.04	......	......	22.4	SO_3 (soluble)-0.0, S (total) -0.2
	Composite A-20 to A-33	Niagaran....	Sub-woolrock..	20.4	5.2	2.0	.....	16.0	22.4	33.6	0.03	......	......	34.0	SO_3 (soluble)-0.0, S (total) -0.3
	Composite A-34 to A-47	Niagaran....	Sub-woolrock..	40.2	8.8	2.4	.....	10.8	12.7	19.7	0.11	......	......	20.8	SO_3 (soluble)-0.0, S (total) -0.3
	Composite A-48 to A-56	Niagaran....	Sub-woolrock..	20.8	5.1	2.1	.....	15.6	21.3	33.0	0.02	......	......	33.0	SO_3 (soluble)-0.0, S (total) -0.3
	NF-59a...	Niagaran....	Woolrock......	28.86	7.39	0.84	.....	13.60	17.15	25.81	0.55	......	......	28.20	TiO_2-0.31, FeO-1.17, Na_2O-0.10, K_2O-2.09, SO_3-0.07, S-0.29, H_2O+-1.30
	NF-60....	Niagaran....	Woolrock......	31.2	9.15	1.95	.....	12.9	17.7	......	0.48	0.7	26.4	......	

TABLE 1—*Chemical analyses of bedrock materials in economically favorable areas*—Continued

Area	Sample No.	Formation	Material	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	MgO	CaO	CO_2	H_2O-	Loss on ignition 110°-400° C.	Loss on ignition 400°-1000°C.	Loss on ignition	Other constituents
Blue Island (cont.)	NF-61	Niagaran	Sub-woolrock	15.40	4.00	0.58	.....	16.77	24.47	36.32	0.05	.....	.....	36.88	TiO_2–0.20, FeO–0.98, Na_2O–0.06, K_2O–0.69, SO_3–0.16, S–0.26, H_2O+–0.85
	NF-96	Niagaran	Woolrock	26.95	6.45	1.36	.....	13.60	19.62	.....	0.35	0.52	29.76	.....	K_2O and Na_2O as Na_2O–2.32
	NF-155	Niagaran	Woolrock	.....	.....	.....	.....	.....	.....	.....	.....	.....	26.5	.....	
	NF-156	Niagaran	Sub-woolrock	.....	.....	.....	.....	.....	.....	.....	.....	.....	37.1	.....	
	NF-157	Niagaran	Sub-woolrock	.....	.....	.....	.....	.....	.....	.....	.....	.....	37.4	.....	
	NF-158	Niagaran	Sub-woolrock	.....	.....	.....	.....	.....	.....	.....	.....	.....	33.9	.....	
	NF-159	Niagaran	Sub-woolrock	.....	.....	.....	.....	.....	.....	.....	.....	.....	30.4	.....	
Divine P. 109	DS-94	Maquoketa	Sub-woolrock	35.26	13.61	4.52	.....	4.67	17.26	.....	0.58	2.60	17.14	20.32	
DuQuoin P. 23	DS-18	Caprock coal No. 6	Sub-woolrock	23.31	5.67	2.32	.....	3.49	33.78	30.17	0.20	.....	.....	31.35	
	DS-19	Caprock coal No. 6	Sub-woolrock	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.5	.....	
	DS-20	"Coal Measures"	Shale	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.12	.....	
	NF-68	Caprock coal No. 6	Sub-woolrock	11.7	6.43	2.37	.....	2.1	43.0	.....	0.14	1.3	34.1	.....	

	NF-69....	Caprock coal No. 6.....	Sub-woolrock..	9.8	.....	.....	4.7	1.3	47.1	......	0.09	0.6	37.7	......	
	NF-73....	Caprock coal No 6.....	Woolrock......	26.9	4.92	2.08	.....	2.1	34.0	......	0.09	1.3	28.5	......	Na_2O and K_2O as K_2O–1.4
	NF-77....	Caprock coal No. 6.....	Woolrock......	29.1	7.49	2.21	.....	2.7	30.3	......	0.80	1.7	25.7	......	MnO–0.07
East St. Louis.... P. 83	NF-80....	Caprock coal No. 6.....	Limestone.....	7.0	.....	.....	4.8	2.9	46.5	......	0.13	0.0	38.9	......	
	NF-82....	Caprock coal No. 6.....	Calcareousshale	55.6	.....	.....	14.9	2.3	12.2	......	1.04	1.1	12.2	......	Na_2O and K_2O as K_2O–2.8
	NF-83....	Caprock coal No. 6.....	Woolrock......	27.9	4.07	4.43	.....	7.3	27.6	......	0.16	0.9	26.9	......	MnO–0.15, Na_2O and K_2O as K_2O –0.7
	NF-84....	St. David...	Sub-woolrock..	15.3	.....	.....	3.1	0.6	45.4	......	0.04	0.2	35.9	......	
	NF-85....	Caprock coal No. 5.....	Woolrock......	23.6	5.13	3.87	.....	3.1	33.7	......	0.54	0.6	29.6	......	
	NF-192...	Warsaw.....	Sub-woolrock..	.....	.....	.....	.....	......	......	......	......	......	33.5	......	
Elgin-Aurora.. P. 89	DS-98.....	Maquoketa..	Calcareousshale	40.75	12.97	3.56	.....	7.62	16.98	14.81	0.79	......	......	17.87	

TABLE 1—*Chemical analyses of bedrock materials in economically favorable areas*—Continued

Area	Sample No.	Formation	Material	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	MgO	CaO	CO_2	H_2O-	Loss on ignition 110°-400° C.	Loss on ignition 400°-1000°C.	Loss on ignition	Other constituents
Elgin-Aurora.. (cont.)	NF-28....	Niagaran....	Sub-woolrock..	14.71	3.04	0.76	.....	17.54	24.86	37.51	0.15	......	......	38.52	TiO_2–0.14, FeO–0.26, Na_2O–Tr, K_2O–0.18, SO_3–0.08, S–0.12, H_2O+–0.64
	NF-29....	Niagaran....	Woolrock......	29.7	6.88	1.52	.....	13.5	19.1	......	1.25	0.5	28.4	......	
	NF-38....	Niagaran....	Dolomite......	11.8	.....	.....	3.4	18.5	27.0	......	0.28	0.4	39.8	......	
	NF-39....	Niagaran....	Sub-woolrock..	45.4	10.30	1.80	.....	8.8	11.7	......	0.28	0.5	18.2	......	Na_2O and K_2O as K_2O–4.6
	NF-40....	Niagaran....	Dolomite......	10.06	2.44	0.64	.....	18.40	26.59	40.27	0.27	......	......	40.82	TiO_2–0.13, FeO–0.60, Na_2O–0.07, K_2O–0.53, SO_3–0.09, S–0.21, H_2O+–0.54
	NF-41....	Kankakee...	Dolomite......	4.8	.....	.....	1.5	20.3	29.5	......	0.10	0.3	43.6	......	
	NF-46....	Maquoketa..	Woolrock......	29.4	10.58	2.92	.....	11.6	16.6	......	2.54	1.2	24.6	......	Na_2O and K_2O as K_2O–3.2
Freeburg... P. 28	DS-33.....	"Coal Measures"	Sub-woolrock..	.....	.....	.....	.....	.....	.....	.....	.....	......	35.2	......	

	NF-78....	"Coal Measures"	Interbedded shale, coal and limestone	33.6	11.03	4.67	.....	1.1	14.1	......	1.95	......	......	(b)29.6	SulphideS 4 4, SO_3-1 4
	NF-79....	Caprock Coal No. 6.....	Woolrock......	28.5	6.18	2.92	.....	1.1	32.4	......	0.56	1.7	25.6	......	MnO-0.14, Na_2O and K_2O as K_2O-1.2
Gale-Grand Tower...	La-7......	Bailey......	Woolrock......	33.58	1.03	1.21	.....	2.27	32.58	28.05	......	......	......	......	
P. 31	NF-70....	Bailey......	Woolrock......	36.3	2.18	1.42	.....	2.9	31.5	......	0.15	0.3	26.4	......	
	NF-91....	Bailey......	Woolrock......	37.25	3.21	1.12	.....	2.30	30.37	......	0.28	0.17	25.31	......	
	NF-92....	Bailey......	Woolrock......	41.44	3.93	1.10	.....	2.82	26.82	......	0.25	0.25	23.22	......	
	NF-93....	Bailey......	Woolrock......	31.53	2.96	1.07	.....	1.65	34.55	......	0.14	0.24	27.75	......	
	NF-94....	Bailey......	Woolrock......	31.81	2.64	1.74	.....	2.90	33.21	......	0.18	0.29	28.06	......	
JoDaviess-	DS-71S...	Maquoketa..	Sub-woolrock..	48.93	10.43	3.68	.....	6.80	10.85	......	0.66	1.47	14.58	16.71	
Stephen-	DS-72.....	Silurian.....	Sub-woolrock..	19.66	4.27	1.56	.....	16.30	23.24	33.76	0.0	......	......	34.60	TiO_2-0.38
son	DS-73.....	Silurian.....	Dolomite......	.....	.....	.....	.....	.....	......	......	......	......	43.6	......	
County..	DS-74.....	Maquoketa..	Woolrock......	29.66	.....	.....	13.14	11.61	17.43	......	0.75	1.11	27.21	......	
P. 39	DS-76.....	Maquoketa..	Shale.........	44.97	16.23	5.46	.....	5.38	9.74	12.42	0.86	......	......	18.00	
	DS-77.....	Maquoketa..	Sub-woolrock..	11.74	4.82	1.29	.....	16.64	25.73	36.90	0.14	......	......	39.51	
	NF-97A...	Maquoketa..	Sub-woolrock..	.....	.....	.....	.....	.....	......	......	0.54	0.86	31.71	......	
	NF-98A...	Silurian.....	Sub-woolrock..	27.11	1.48	0.55	.....	14.92	23.54	......	0.05	0.28	33.12	33.45	
	NF-99....	Maquoketa..	Woolrock......	29.76	7.95	2.82	.....	12.21	17.74	......	0.24	0.57	26.34	27.15	
Kankakee..	L-107 (c)..	Niagaran....	Sub-woolrock..	11.36	.....	.....	6.10	(d)16.8	(d)24.9	(d)37.9	0.86	......	......	......	
P. 95	NF-95....	Niagaran....	Sub-woolrock..	21.02	5.41	1.70	.....	15.55	22.49	......	0.86	0.20	33.60	......	
	NF-154...	Niagaran....	Woolrock......	34.47	7.62	2.03	.....	11.51	16.51	......	0.30	1.11	24.59	25.70	

TABLE 1—*Chemical analyses of bedrock materials in economically favorable areas*—Continued

Area	Sample No.	Formation	Material	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	MgO	CaO	CO_2	H_2O—	Loss on ignition 110°-400° C.	Loss on ignition 400°-1000°C.	Loss on ignition	Other constituents
LaSalle.... P. 50	C-11a (*e*)..	LaSalle......	Woolrock......	26.18	....	....	11.00	5.34	28.82	.....	0.22	.....	.....	29.56	
	C-11b (*e*)..	LaSalle......	Sub-woolrock..	22.76	....	....	11.10	2.82	31.20	.....	0.41	.....	.....	32.78	
	DX-15....	LaSalle......	Limestone.....	....	....	....	....	.....	.....	.....	.....	.....	40.78	.....	
	DX-17A...	LaSalle......	Woolrock......	29.07	5.13	3.34	....	3.30	29.79	27.38	1.14	.....	.....	29.41	
	DX-17B...	LaSalle......	Woolrock......	26.4	4.8	2.7	....	2.4	32.1	.....	0.40	.....	.....	30.7	
	DX-20....	LaSalle......	Sub-woolrock..	16.83	4.32	2.06	....	1.95	40.25	32.94	0.22	.....	.....	33.93	Na_2O-0.26, K_2O-0.60
	E-15a (*e*)..	LaSalle......	Sub-woolrock..	23.30	....	....	8.64	2.96	33.86	.....	0.46	.....	.....	32.38	
	E-15b (*f*)..	"Coal Measures".	Shale.........	49.10	....	....	27.34	2.74	7.94	.....	.....	.....	.....	12.88	
	NF-193...	"Coal Measures".	Woolrock......	....	....	....	....	.....	.....	24.66	.....	.....	.....	.....	
	NF-194...	"Coal Measures".	Shale.........	....	....	....	....	.....	.....	8.60	.....	.....	.....	.....	
	NF-195...	"Coal Measures".	Woolrock......	....	....	....	....	.....	.....	26.48	.....	.....	26.9	.....	
	NF-196...	"Coal Measures".	Sub-woolrock..	....	....	....	....	.....	.....	16.15	.....	.....	17.2	.....	
	NF-197...	"Coal Measures".	Woolrock......	....	....	....	....	.....	.....	30.01	.....	.....	.....	.....	
	NF-198...	"Coal Measures".	Shale.........	....	....	....	....	.....	.....	10.04	.....	.....	.....	.....	
	NF-199...	"Coal Measures".	Shale.........	....	....	....	....	.....	.....	3.52	.....	.....	.....	.....	

	NF-200	"Coal Measures"	Sub-woolrock	.....	.....	.....	.....	.....	.....	.....	.....	.....	31.2	.....	
	NF-201	"Coal Measures"	Shale	.....	.....	.....	.....	.....	.....	4.31	.....	.....	.....	.....	
	W-7	"Coal Measures"	Shale	56.40	18.97	8.86	.....	2.13	2.32	1.06	0.35	.....	.....	6.90	TiO_2–0.92, Na_2O–0.85, K_2O–3.21, S–0.00
	W-91	LaSalle	Sub-woolrock	20.45	3.36	2.22	.....	3.64	36.73	32.06	0.10	.....	.....	32.96	TiO_2–0.19, Na_2O–0.22, K_2O–0.57, S–0.00
Lemont, P. 97	DX-4	Niagaran	Sub-woolrock	24.84	1.13	1.85	.....	15.01	22.99	.....	0.15	0.38	34.29	.....	
	DX-5	Niagaran	Woolrock	41.08	2.01	1.88	.....	11.95	17.49	.....	0.19	0.40	25.51	.....	
Milan, P. 110	DS-68	Devonian	Limestone	.....	.....	.....	.....	.....	.....	.....	.....	.....	41.44	.....	
	DS-69	Devonian	Sub-woolrock	13.42	5.13	2.41	.....	3.75	39.30	34.73	0.33	.....	.....	36.06	
Oregon, P. 99	NF-124	Shakopee	Sub-woolrock	22.10	1.81	1.10	.....	15.86	23.90	.....	0.06	0.31	35.08	35.44	
	NF-125	Shakopee	Woolrock	34.37	8.56	2.30	.....	11.53	18.24	.....	0.65	0.65	23.62	24.92	
Pontiac, P. 100	DS-99	"Coal Measures"	Sub-woolrock	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.78	.....	
	P-4(*g*)	"Coal Measures"	Sub-woolrock	25.34	1.13	0.51	.....	0.43	38.59	*d*)30.76	.....	.....	.....	.....	
	P-10(*g*)	"Coal Measures"	Woolrock	36.64	11.80	2.20	.....	*d*)1.61	*d*)23.61	*d*)20.28	.....	.....	.....	.....	
	P-11(*g*)	"Coal Measures"	Woolrock	21.23	9.47	2.53	.....	1.93	34.60	*d*)29.26	.....	.....	.....	.....	
Thornton, P. 104	NF-57	Pleistocene	Clay	48.4	.....	.....	17.5	6.4	10.1	.....	0.42	3.0	12.3	.....	Na_2O and K_2O as K_2O–4.0
	NF-58	Niagaran	Sub-woolrock	14.6	.....	.....	4.3	17.5	26.3	.....	0.01	0.8	37.7	.....	

TABLE 1—*Chemical analyses of bedrock materials in economically favorable areas*—Concluded

Area	Sample No.	Formation	Material	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	MgO	CaO	CO_2	H_2O—	Loss on ignition 110°-400° C.	Loss on ignition 400°-1000°C.	Loss on ignition	Other constituents
Utica......	C-14a (h)..	Shakopee....	Dolomite......	15.02	.....	.....	8.20	12.50	25.40	......	0.33	......	......	38.54	
P. 105	C-14b (h)..	Shakopee....	Dolomite......	14.42	.....	.....	11.34	9.82	26.12	......	0.12	......	......	38.80	
	DS-56.....	Shakopee....	Dolomite......	11.59	1.77	1.24	.....	17.88	26.56	40.05	0.06	......	......	40.37	
	DS-57.....	Shakopee....	Dolomite......	12.65	1.58	1.18	.....	18.89	25.42	39.46	0.10	......	......	39.60	
	DX-18....	Shakopee....	Sub-woolrock..	16.10	6.57	1.60	.....	13.98	24.05	37.19	......	......	......	37.43	
	DX-19....	Shakopee....	Sub-woolrock..	23.05	1.64	1.64	.....	16.23	23.73	......	0.01	0.36	34.48	34.85	
	W-82.....	Shakopee....	Dolomite......	7.74	1.39	1.05	.....	19.11	27.86	42.15	0.07	......	......	42.73	TiO_2-0.0, Na_2O-0.02, K_2O-0.80
Valmeyer..	NF-89....	Decorah?....	Woolrock......	40.2	0.33	2.07	.....	0.8	31.4	......	0.0	0.0	24.6	......	
P. 102	NF-90....	Keokuk-Burlington....	Sub-woolrock..	24.4	.....	.....	1.2	1.5	40.2	......	0.08	0.2	32.3	......	

(*a*) The analyses in this table, except where otherwise acknowledged, have been made in the Analytical Division of the State Geological Survey by C. S. Westerberg and L. D. McVickers under the direction of Dr. O. W. Rees.

(*b*) Includes CO_2, H_2O+, and carbon present as coal.

(*c*) Ill. Geol. Survey Bull. 46, 1926, p. 320.

(*d*) Calculated from $CaCO_3$ and $MgCO_3$.

(*e*) Ill. Geol. Survey Bull. 17, 1912, p. 97.

(*f*) Ibid, p. 104.

(*g*) Ill. Geol. Survey Rept. Invest. 17, 1929, pp. 13, 14, 16.

(*h*) Ill. Geol. Survey Bull. 17, 1912, p. 98.

WORKABILITY OF DEPOSITS UNCERTAIN

Blue Island Area

(Cook County)

SUMMARY

Data assembled from studies of (1) the material in the spoil banks along the Calumet Sag Channel, (2) outcrops, and (3) the cores of four borings in the area west and south of the town of Blue Island, a short distance southwest of Chicago, suggest that in places there is present as much as 45 feet of rock, including woolrock, sub-woolrock, and associated dolomite, which as a unit have an average chemical composition that falls within the composition limits of woolrock. Detailed prospecting by drilling is needed to evaluate the rock wool making possibilities of the area. The data at hand are favorable to the possibility of finding commercial deposits of woolrock.

INTRODUCTION

The Blue Island area lies west and south of the town of Blue Island and partly along the Calumet Sag Channel (Fig. 10). This channel or canal was dug partly in glacial clay and partly in the underlying Silurian dolomite and the material excavated was heaped into spoil banks on either side of the channel. A dark or medium gray dolomite which weathers into thin, irregular pieces and for this reason is subsequently described as "shelly", occurs in the spoil heaps and was found to be a woolrock. One outcrop was also noted which included among other beds, 2 feet of woolrock. The data available regarding the actual occurrence of the woolrock, however, was so meager that very little could be deduced concerning its thickness and distribution. Through the courtesy of the Illinois Division of Highways, Department of Public Works and Buildings, four diamond drill borings were made for the Survey in the Blue Island area. The cores from these borings show that considerable thicknesses of woolrock or sub-woolrock are present in places.

DESCRIPTION OF SPOIL BANKS

Spoil banks occur on both sides of the Sag channel and range from 10 to 45 feet in height and from 100 to 200 feet in width at the base. The material varies considerably; at some places that visible is largely dolomite, at others it is pebbly clay. The material comprising the central portion is not always the same as the material on the surface.

Medium to thick bedded dolomite, excavated from the bedrock, is found with or without "shelly" dolomite in most parts of the spoil banks except where they are composed entirely of till. Data regarding the distribution of the shelly dolomite observed follow.

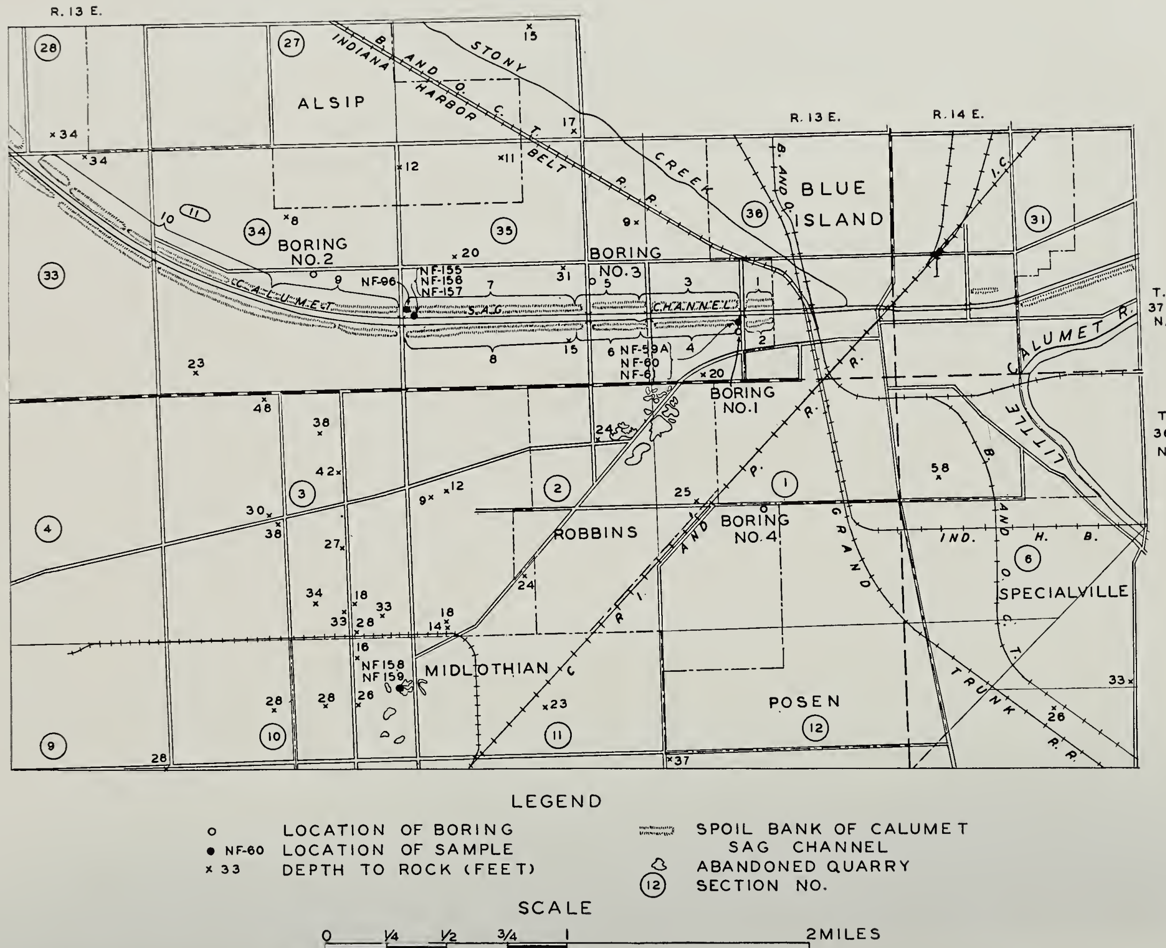


FIG. 10. Map of Blue Island area showing locations at which four borings were made and where samples were taken.

East of Blue Island the shelly dolomite is present in the spoil banks near the center of the S. ½ sec. 31, T. 37 N., R. 14 E., but is mixed with earth and clay.

West of Blue Island those parts of the spoil bank marked "1" and "2" in figure 10, contain fragments of shelly dolomite but are probably largely till.

Part 3 of the spoil pile shows largely shelly dolomite. At the west end till is exposed as the core of the dump, but about 300 feet to the east a cut to the base of the pile shows much shelly dolomite and no till.

Part 4 of the spoil heap contains much shelly dolomite but probably has a till core, especially near the west end. Three samples were obtained from the blocks of stone exposed in the east end of this part of the pile. *NF-59a* consists of shelly dark gray dolomite, *NF-60* of shelly greenish-gray dolomite, and *NF-61* of cream or buff colored dolomite occurring in large solid blocks. Samples *NF-59a* and *NF-60* were found to be woolrock, and Sample *NF-61* a sub-woolrock (Table 1, pp. 57, 58; also pp. 162, 165).

Parts 5 and 6 of the spoil bank show mainly till.

Parts 7 and 8 are 35-40 feet high and show some shelly dolomite. They probably have a till core throughout since till is exposed as the core of the pile in a number of places. The shelly dolomite is present in lesser amounts than in the spoil banks farther east which suggests that the thickness of shelly dolomite encountered was less. Sample *NF-96,* collected from the shelly dolomite at the west end of Part 7, was found to be woolrock, (Table 1 and pp. 164, 165).

Part 9 of the spoil bank is largely till at the surface.

Part 10 shows shelly dolomite but also considerable till. The shelly dolomite encountered was evidently a thin stratum.

West of part 10, the spoil bank is largely till at the surface and the typical shelly dolomite noted farther east was not observed. Apparently the canal did not penetrate the shelly dolomite west of part 10.

At location 11, in the NW. ¼ sec. 34, T. 37 N., R. 13 E. (Fig. 10), a drainage ditch, now about 10 feet deep, encountered shelly dolomite which is not now exposed but blocks of it are present in the small dump pile along the ditch.

DESCRIPTION OF OUTCROPS AND QUARRIES

CRAWFORD AVENUE OUTCROP

The one outcrop of woolrock noted occurs along the Sag Channel for about ¼ mile east of the Crawford Avenue bridge in the W. ½ SW. ¼ sec. 35, T. 37 N., R. 13 E. (Fig. 10), and is probably covered at times of high water in the Sag Channel. The exposure and samples obtained from it are as follows:

Exposure east of Crawford avenue bridge

	Thickness Feet
Covered, rip-rapped bank of channel, probably clay	15
3. Dolomite, dark gray with black mottlings, dense, argillaceous; weathers to thin slabs; grades into underlying bed. Sample *NF-155*	2
2. Dolomite, dark gray, slightly crystalline, with gnarly structure; grades into underlying bed. Sample *NF-156*	1
1. Dolomite, gray, finely crystalline, hard, in beds 2 to 6 inches thick, weathers rusty brown. Sample *NF-157*	1
Covered, level of water in canal	

Sample *NF-155* is shown by analysis (Table 1) to be a woolrock. Samples *NF-156* and *157* are sub-woolrocks.

QUARRIES AT ROBBINS

Several abandoned quarries located near Robbins in the W. ½ NW. ¼ NW. ¼ sec. 1 T. 36 N., R. 13 E., and the E. ½ NE. ¼ sec. 2 of the same township may have encountered shelly dolomite. These quarries have been abandoned for many years and are now filled with water or refuse. Earlier reports give meager information regarding the thickness or specific character of the beds exposed. The stone was used for foundation stone and for making hydraulic cement.[23] The chemical composition of the rock used for making cement is shown in the analysis below, which is fairly similar to the results of analyses of the shelly dolomite from the spoil bank.

Analysis of stone from Blue Island quarries[24]

Clay and insoluble matter	43.56
Calcium carbonate	31.60
Magnesium carbonate	22.24
Iron peroxide	1.20
Soluble silica	0.16
Alkalies, loss, etc	1.30
	100.06

None of the stone formerly quarried at Robbins is now available except the rock comprising the rim of the quarries. A sample of this stone from about 18 inches of buff dolomite exposed in a ditch along the concrete road in center S. ½ SE. ¼ NE. ¼ NE. ¼ sec. 2 was 25 per cent insoluble in acid and is, therefore, higher in carbonates than the cement rock in the quarries or the shelly dolomite in the spoil bank. It is probably a sub-woolrock.

[23] Bannister, H. M., Geology of Illinois, vol. III, 1868, p. 247.
[24] Bannister, H. M., Op. cit., p. 574.

QUARRIES AT MIDLOTHIAN

Several waterfilled, long-abandoned quarries occur in the northwest part of Midlothian in the E. ½ of the NE. ¼ sec. 10, T. 36 N., R. 13 E. When in operation these quarries are said[25] to have produced foundation stone which it is inferred was obtained from about the same horizon as the stone quarried for foundation stone at Robbins. Whether or not the strata used for making hydraulic cement at Robbins were exposed in the Midlothian quarries is not definitely stated.

No rock is now exposed at Midlothian. Two samples, however, were obtained from loose, mostly weathered, slabs lying in the vicinity of the quarries in the SE. ¼ NE. ¼ NE. ¼ sec. 10. Sample *NF-158* consists of slabs of brown or buff stone and *NF-159* of slabs of gray, argillaceous rock. Results of tests (Table 1) indicate that both are sub-woolrocks although *NF-159* is closely bordering on woolrock.

BORINGS AT BLUE ISLAND

Data regarding the cores obtained from borings at Blue Island and results of CO_2 determinations on core samples are given in tabular form (Tables 2-5 and Fig. 11). It is to be noted that a continuous section of core was not obtained in any of the borings. The depths at a number of points in each of the borings is known, however, so that the approximate position of any particular unit of core is known within reasonable limits. The places where losses of core are most likely to have occurred are indicated on the basis of drilling notes and the character of the cores.

---

[25] Bannister, H. M., Op. cit., p. 247.
Alden, Wm. C., Geological Atlas of the United States, U. S. Geol. Survey, Chicago Folio (No. 81), p. 12, 1902.

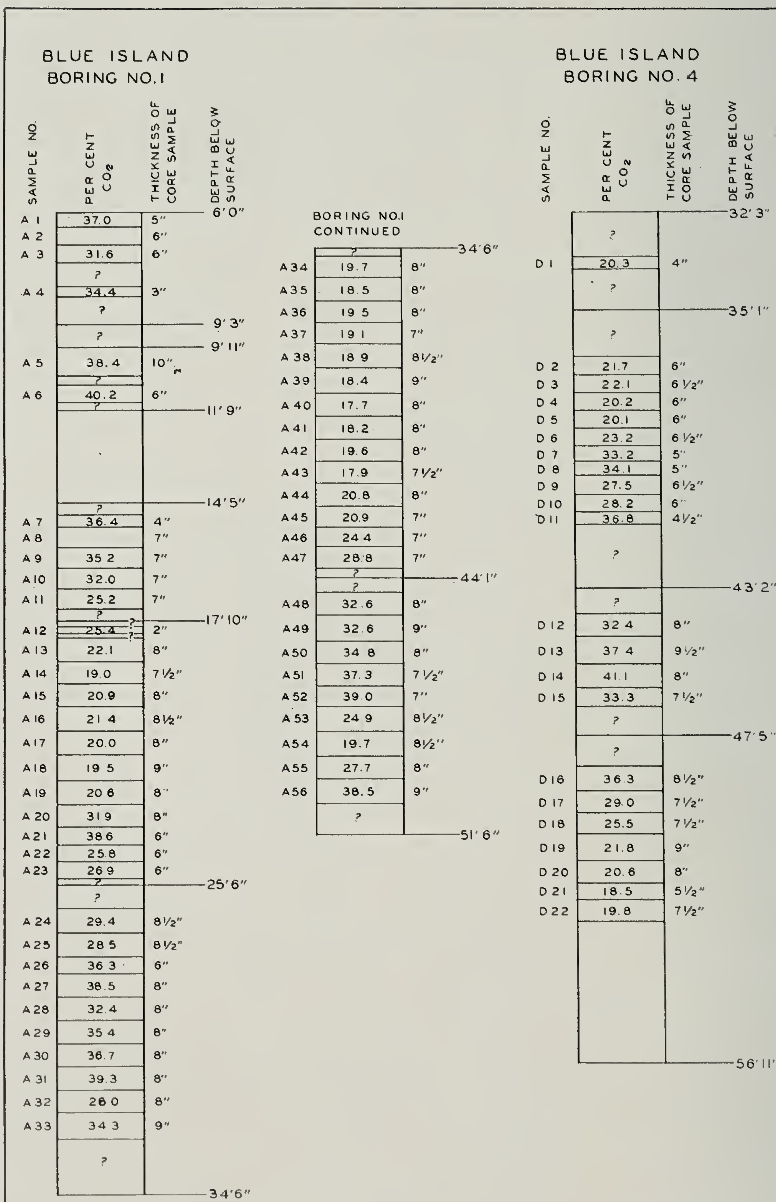


FIG. 11. Diagram showing per cent of CO_2 (loss on ignition 400°-1000° C.) in samples from cores of the Niagaran dolomite in the Blue Island area. The first figure in the column "Depth below surface" indicates the thickness of unconsolidated material, mostly clay, penetrated before bedrock was reached. The interrogation points (?) show the probable position of intervals from which core was not recovered.

Table 2—*Physical description of cores*

Blue Island Boring No. 1

Location—NW. ¼ SE. ¼ SW. ¼ sec. 36, T. 37 N., R. 13 E., 35 feet west of center of N–S road and 15 feet north of center of E–W secondary road along south boundary of Sanitary District property; or 480 feet south of center of Sag Channel and 375 feet north of center of paved road.

Elevation—593 feet (hand level).

Sample No.	Condition of core	Depth		Thickness of rock penetrated	Total length of core	Length of core in samples for chemical analysis Inches
		From	To			
	Surface soil and yellow clay	0	6′			
A-1* A-2 A-3* A-4*	Continuous section of core; probably from top of bedrock downward Separate piece of core	6′0″	9′3″	3′3″	1′8″	5 6 6 3
	Core in small pea sized pieces—not tested	9′3″	9′11″	0′8″	1″	
A-5* A-6*	Continuous section of core Section of core not continuous, parts probably missing at top and bottom	9′11″	11′9″	1′10″	1′4″	10 6
	Core too small for sample—not tested	11′9″	14′5″	2′8″	1″	
A-7* A-8 A-9* A-10* A-11*	Continuous section of core. Missing core probably at top and bottom	14′5″	17′10″	3′5″	2′8″	4 7 7 7 7

TABLE 2—Continued

Sample No.	Condition of core	Depth		Thickness of rock penetrated	Total length of core	Length of core in samples for chemical analysis Inches
		From	To			
A-12*	Broken fragments of core					2
A-13*						8
A-14*						7½
A-15*						8
A-16*						8½
A-17*		17′10″	25′6″	7′8″	7′1″	8
A-18*	Loss of core probably at top and					9
A-19*	bottom and one small break 12″					8
A-20*	from base of core					8
A-21*						6
A-22*						6
A-23*						6
A-24*						8½
A-25*						8½
A-26*						6
A-27*						8
A-28*	Loss of core mostly at bottom	25′6″	34′6″	9′0″	6′8″	8
A-29*						8
A-30*						8
A-31*						8
A-32*						8
A-33*						9
A-34*						8
A-35*						8
A-36*						8
A-37*						7
A-38*						8½
A-39*						9
A-40*						8
A-41*		34′6″	44′1″	9′7″	9′1″	8
A-42*						8
A-43*						7½
A-44*						8
A-45*						7
A-46*						7
A-47*						7

TABLE 2—Continued

Sample No.	Condition of core	Depth		Thick-ness of rock pene-trated	Total length of core	Length of core in samples for chemical analysis Inches
		From	To			
A-48*	Loss probably mostly in lower 4 feet of core	44′1″	51′6″	7′5″	6′1½″	8
A-49*						9
A-50*						8
A-51*						7½
A-52*						7
A-53*						8½
A-54*						8½
A-55*						8
A-56*						9

* Sample analized for CO_2. (Loss on Ignition 400°–1000°C.)

TABLE 2—Continued

Blue Island Boring No. 2

Location—NE. cor. NW. ¼ NW. ¼ SE. ¼ sec. 34, T. 37 N., R. 13 E., 35 feet S. of center of E–W road and 25 feet SW. of westernmost tree in isolated group of trees or 1,800 feet east of angle in main E–W road.
Elevation—598 feet (hand level).

Sample No.	Condition of core	Depth		Thickness of rock penetrated	Total length of core	Length of core in samples for chemical analysis Inches
		From	To			
	Glacial clay, bouldery	0	17′9″			
B-1* B-2 B-3* B-4 B-5*	Loss probably scattered throughout entire interval	17′9″	22′4″	4′7″	3′0″	7 7 7 7 8
B-6*	Loss probably in upper 6 inches	22′4″	23′10″	1′6″	1′0″	12
B-7* B-8 B-9* B-10 B-11*	Loss mostly at bottom	23′10″	29′0″	5′2″	3′4″	8 8 8 8 8
B-12* B-13 B-14* B-15 B-16*	Loss of core mostly at bottom	29′0″	34′2″	5′2″	3′7″	9 9 9 8 8
B-17 B-18* B-19 B-20	Loss of core mostly at bottom	34′2″	38′10″	4′8″	2′6½″	8 8 7½ 7
B-21 B-22* B-23 B-24*	Lost core mostly at bottom	38′10″	43′6″	4′8″	2′3½″	6½ 7 7½ 6½
B-25		43′6″	43′7″	1″	1″	1

* Sample analized for CO_2.

TABLE 2—Continued

Blue Island Boring No. 3 *(a)*

Location—NW. ¼ NW. ¼ NE. ¼ SE. ¼ sec. 35, T. 37 N., R. 13 E., 375 feet south of center of cross roads and 25 feet east of center of N–S road.
Elevation—596 feet (hand level)

Sample No.	Condition of core	Depth		Thickness of rock penetrated	Total length of core	Length of core in samples for chemical analysis Inches
		From	To			
	Bouldery clay	0	19′6″			
C- 1*		19′6″	19′11″	5″	4″	4
C- 2*	Sample probably from top of interval	24′3″	29′0″	4′9″	10″	10
C- 3* C- 4 C- 5* C- 6 C- 7* C- 8 C- 9* C-10	Loss probably distributed throughout	25′1″	33′8″	8′7″	4′2″	6 6 6 7 6 6 6 7
C-11* C-12 C-13* C-14		33′8″	36′10″	3′2″	2′½″	7 5½ 6 6
C-15* C-16 C-17* C-18 C-19* C-20 C-21* C-22 C-23* C-24 C-25* C-26 C-27* C-28 C-29*		36′10″	47′7″	10′9″	9′11″	8 8 8 8 8 8 8 8 8 8 8 8 8 7 8

* Sample analized for CO_2.

(a) Three holes were drilled at this location in an attempt to obtain a complete core of the upper part of the bedrock.

Sample C-1 was obtained from one hole, C-2 from another, and the remainder of the core from the third hole.

TABLE 2—Concluded

Blue Island Boring No. 4

Location—NE. ¼ NE. ¼ NE. ¼ SW. ¼ sec. 1, T. 36 N., R. 13 E., 40 feet south of center of E–W road and 15 feet west of the fire hydrant; or 0.2 mile east of C. R. I. & P. R. R. and 0.3 mile west of Grand Trunk R. R. along road marking south boundary of town of Blue Island.

Elevation—598 feet (hand level).

Sample No.	Condition of core	Depth From	Depth To	Thickness of rock penetrated	Total length of core	Length of core in samples for chemical analysis Inches
	Boulder clay	0	32′3″			
D- 1*	Position of core sample unknown	32′3″	35′1″	2′10″	4″	4
D- 2*						6
D- 3*						6½
D- 4*						6
D- 5*						6
D- 6*	Position of loss unknown	35′1″	43′2″	8′1″	4′10″	6½
D- 7*						5
D- 8*						5
D- 9*						6½
D-10*						6
D-11*						4½
D-12*						8
D-13*	Loss principally at top and bottom	43′2″	47′5″	4′3″	2′9″	9½
D-14*						8
D-15*						7½
D-16*						8½
D-17*						7½
D-18*						7½
D-19*	Loss principally at base	47′5″	56′11″	9′6″	4′5½″	9
D-20*						8
D-21*						5½
D-22*						7½

* Sample analized for CO_2.

Table 3—*Lithologic description of cores*

Boring No. 1

Sample No.	
A-1 to A-5	Dolomite, fine grained, light gray; a few pyrite masses.
A-6 and 7	Dolomite, fine grained, mottled gray and light gray.
A-8 to A-20	Dolomite, fine grained, light gray; a few pyrite masses.
A-21	Dolomite, fine grained, mottled gray and light gray.
A-22 to A-25	Dolomite, fine grained, dark gray-brown, in part streaked with fine white bands.
A-26 to A-31	Dolomite, mostly fine grained, light gray. Two bands of medium to coarsely crystalline dolomite, one of them mottled, gray and light gray. In sample A-28 there is about 3 inches of core which is finely banded gray and white.
A-32 to A-49	Dolomite, fine grained, gray; pyrite rare.
A-50 to A-52	Dolomite, fine grained, mottled gray and light gray; pyrite rare.
A-53 to A-55	Dolomite, fine grained, light gray, pyrite rare.
A-56	Dolomite, fine grained, mottled gray and light gray.

Boring No. 2

Sample No.	
B-1 to B-4	Dolomite, fine grained; light gray; scattered pyrite masses.
B-5 and B-6	Dolomite, like above, but pyrite very abundant as a result of coring through a pyrite vein.
B-7	Dolomite, like B-1 to B-4.
B-8 and B-9	Dolomite, fine grained, light gray-brown, streaked with dark gray.
B-10	Dolomite, upper half like B-8 and B-9, lower half like B-11 to B-18.
B-11 to B-18	Dolomite, fine grained, light gray, locally abundant pyrite.
B-19	Dolomite, fine grained, mottled gray and light gray.
B-20	Upper two inches of core like B-19, lower part like B-21 to B-23.
B-21 to B-23	Dolomite, fine grained, light gray.
B-24 and B-25	Dolomite, mottled light gray and gray.

Boring No. 3

Sample No.	
C-1	Dolomite, fine grained, light gray, slightly mottled with gray; a little pyrite.
C-2 to C-6	Dolomite, fine grained, light gray; a little pyrite.
C-7 to C-29	Dolomite, fine grained, mostly mottled light gray and gray with mottling of various degrees of intensity; pyrite locally common.

Boring No. 4

Sample No.	
D-1 to D-7	Dolomite, fine grained, gray; a few small masses of pyrite.
D-8	Dolomite, light and dark gray mixed; pyrite abundant, one small crystal of sphalerite.
D-9 and D-10	Dolomite, fine grained, mostly dark gray-brown, banded with fine white streaks.
D-11	Dolomite, mottled gray and dark gray, fine grained; pyrite common.
D-12 to D-16	Dolomite, fine grained, gray, locally mottled; a few small pyrite masses.
D-17 to D-22	Dolomite, fine grained, gray; a few small pyrite masses.

TABLE 4—*Results of rapid CO_2 determinations on samples of core from boring No. 2*

Sample No.	Loss 400–1000° C. *per cent*	Sample No.	Loss 400–1000° C. *per cent*
B–1	33.4	B–14	32.1
B–3	39.1	B–16	37.0
B–5	25.8	B–18	38.1
B–6	37.5	B–20	35.0
B–7	40.6	B–22	31.9
B–9	41.2	B–24	41.2
B–11	33.7		
B–12	33.9		

TABLE 5—*Results of rapid CO_2 determinations on samples of core from boring No. 3*

Sample No.	Loss 400–1000° C. *per cent*	Sample No.	Loss 400–1000° C. *per cent*
C–1	38.9	C–17	34.4
C–2	28.4	C–19	34.1
C–3	26.1	C–21	38.7
C–5	20.1	C–23	34.2
C–7	38.7	C–25	37.2
C–9	38.2	C–27	40.0
C–11	39.8	C–29	32.0
C–13	42.6		
C–15	32.4		

BORING NO. 1

The results of tests on the core of boring No. 1, figure 11, show a notable variation in the CO_2 content. Four units, each comprised of samples having roughly similar CO_2 contents, may be recognized, namely one major unit of woolrock from samples *A-11* to *A-19,* and four major units of sub-woolrock, samples *A-1* to *A-10, A-20* to *A-33, A-34* to *A-47,* and *A-48* to *A-56.* The unit *A-34* to *A-47* is a sub-woolrock having a CO_2 content slightly below the CO_2 limit for woolrock, whereas the CO_2 contents of the other three units of sub-woolrock are above the limit.

The woolrock unit is represented by 6¼ feet of core and the actual thickness of woolrock penetrated was probably a few inches in excess of the thickness of core obtained. The top of the woolrock unit lies at a depth of approximately 17 feet.

In order to obtain more detailed information regarding the chemical character of the above units, analyses were made of composite samples of each unit. The results of analyses are given in Table 1. Chemical data for combinations of these units calculated by weighting the composite analyses according to the thickness of interval which they represent are given below:

	A–11 to 47	A–11 to 56	A–1 to 47	A–1 to 56
SiO_2	31.2	29.0	27.1	26.1
Al_2O_3	7.3	6.9	6.4	6.2
Fe_2O_3	2.2	2.2	2.1	2.1
CaO	17.1	18.0	19.0	19.4
MgO	13.0	13.6	14.0	14.3
CO_2	25.8	27.4	28.7	29.2
	96.6	97.2	97.3	97.3

These calculations show that any of the above four combinations of core samples yield a mixture whose chemical composition lies within the composition limits of woolrock (p. 16).

BORING NO. 2

Boring No. 2 encountered only one sample having the CO_2 content of woolrock, sample *B-5*, and one principal unit of sub-woolrock represented by samples *B-11* to *B-22*. The exact thickness of rock represented by sample *B-5* is not known but it is probably less than 1½ feet. Samples *B-11* to *B-22* probably represented a thickness of about 10 feet of rock. The average CO_2 content of the rock penetrated was 36.0 per cent as calculated from the data in Tables 2 and 4. This suggests that it is a sub-woolrock.

BORING NO. 3

Boring No. 3 encountered woolrock in samples *C-2, C-3,* and *C-5* on which CO_2 determinations were made. The woolrock probably includes samples *C-2* to *C-6* inclusive. The data available from the combined core samples do not indicate definitely the thickness of woolrock penetrated but it is estimated to be about 5 feet.

Samples *C-15* to *C-29* are chiefly sub-woolrock, representing about 11 feet of rock at a depth of 37 feet. The average CO_2 content of the rock penetrated was 33.5 per cent as calculated from data in Tables 2 and 4. This suggests that it is a sub-woolrock.

BORING NO. 4

Boring No. 4 encountered three units of woolrock. The uppermost unit includes samples *D-1* to *D-6* representing the rock penetrated from about 33 to 39 feet or approximately 6 feet of woolrock. The middle unit is represented by samples *D-9* and *D-10* having a thickness of 12½ inches which was encountered at a depth of about 40 feet. The lower unit, samples *D-17* to *D-22,* which is about 8 feet thick and was met at a depth of 49 feet, includes some sub-woolrock whose CO_2 content is very close to that of woolrock (Fig. 11).

Sub-woolrock was encountered in the rock represented by samples *D-7, D-8, D-11, D-12, D-13, D-15,* and *D-16.*

The average CO_2 content weighted according to the thickness of the various units of core is shown below:

Sample No.	CO_2 (Loss on ignition 400° to 1000° C.)
	Per cent
D-2 to *D-11*	26.1
D-12 to *D-15*	36.2
D-16 to *D-22*	24.8
D-1 to *D-22*	27.7

The data from *D-1* to *D-22* suggest that if a complete core were obtained, it also might have an average CO_2 content which would lie within the limits of woolrock.

CHARACTER OF WOOLROCK

The upper and lower major woolrock units encountered in boring No. 4 and the major woolrock unit of boring No. 1 are fine grained, gray or light gray dolomite containing a small amount of clay and a considerable quantity of fine silica. The middle unit in boring No. 4 and the woolrock unit encountered at a depth of about 25 feet in boring No. 1 are banded dark and light gray or white dolomite having an overall brownish cast. The non-calcareous material present is mainly clay and fine silica. The CO_2 content is indicated in figure 11 and the detailed chemical compositions of the individual units of the core of boring No. 1 are shown by the results of analyses of composite samples (Table 1, p. 57).

Data regarding the thickness of the woolrock units have been given in connection with the description of cores and outcrops. Some of the data suggest that the woolrock units vary in thickness laterally.

GENERAL DISTRIBUTION OF WOOLROCK

The data regarding woolrock in the area are so scanty that only very generalized statements are possible concerning its distribution. Information covering its presence in the spoil banks has already been given and from this it is inferred that the bed rises to the west. According to observations made at the Robbins quarries[26] the bedrock strata dip to the southeast 2 to 4 degrees or roughly 200 to 400 feet per mile. The data afforded by the four borings made during the present study suggest that a dip to the southeast or east is present but that the amount of dip is probably less than that noted above. The dip indicated between borings 1 and 4 is about 19 feet per mile.

On the basis of the data at hand, it is thought that the upper woolrock bed and the banded woolrock encountered in boring No. 1 probably comes to the bedrock surface and would outcrop, if no overburden were present, a short

[26] Bannister, H. M., Op. cit., p. 247.

distance east of boring No. 3 and that the lower beds outcrop progressively westward. Irregularities in the surface of the bedrock and local variations in the thickness and structure of the woolrock may alter this distribution in places.

Correlation of the "cement rock," which is probably woolrock, encountered in the Robbins quarries, and of the sub-woolrock picked up from the surface in the vicinity of the Midlothian quarries with the woolrock strata encountered in borings 1 and 4 is impossible from the present data.

CHARACTER OF BEDROCK SURFACE

Figure 10 shows the depth to bedrock at a number of places in the Blue Island area.[27] These data indicate that the bedrock surface is very irregular and has rather marked relief in places, in part probably due to the presence of sink holes. Areas where the bedrock surface is high occur in the vicinity of the Robbins and Midlothian quarries and in these tracts the unconsolidated clay overburden on the rock is thin.

CHARACTER AND THICKNESS OF OVERBURDEN

The overburden on the bedrock is largely pebbly clay with sand and gravel locally present. Comparatively thin deposits of peat and peaty marl are also present in some places. The only data available regarding the thickness of the overburden are the figures showing depth to bedrock given in figure 10.

DEVELOPMENT CONSIDERATIONS

The most favorable areas for prospecting appear to be in the vicinity of borings No. 1 and No. 4. The area around the quarries at Midlothian and Robbins and the intervening tract is also worthy of consideration. Core drilling at Posen and Specialville may encounter woolrock or sub-woolrock but probably at greater depths than at the more western locations, although only presumptive data suggest the presence of woolrock or sub-woolrock in these regions.

As indicated, the woolrock strata in the Blue Island area are comparatively thin and are interbedded with sub-woolrock and dolomite. Certain combinations of these materials, however, yield mixtures which have the CO_2 content of woolrocks as discussed under borings Nos. 1 and 4. If mixtures of this kind can be used, 45 feet or more of such stone may be available locally. In places the stone may be worked by open pit methods, but sub-surface mining appears most feasible in areas where the unconsolidated overburden or the combined unconsolidated and bedrock overburden on the woolrock is thick.

---

[27] The writers are indebted to Mr. George Otto of the Illinois Geological Survey and the University of Chicago for much of the data presented regarding depth to bedrock.

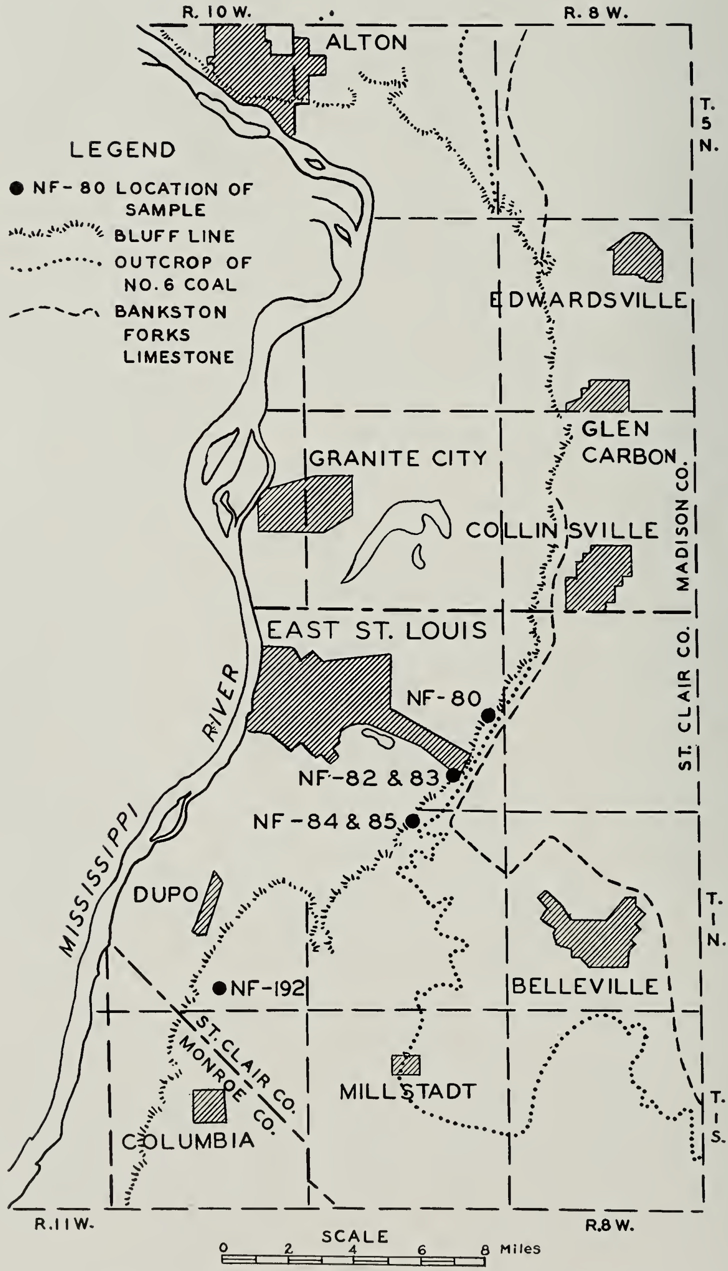


Fig. 12. Map of East St. Louis area showing outcrop of coal No. 6 and Bankston Forks limestone and locations from which samples were taken. (From maps by G. H. Cady and J. M. Weller, State Geological Survey.)

Prospecting by core drilling in the Blue Island area should be thorough and should include careful testing of cores. Visual differentiation of the light gray and gray woolrock from associated beds is difficult and the need of careful chemical examination of cores is therefore emphasized. No data are available concerning the possible occurrence of woolrock or sub-woolrock in the strata underlying those tested in the present investigation. It would appear worth while, however, to prospect the deeper beds at a few places.

It has been pointed out that parts of the spoil banks along the Sag channel contain woolrock or sub-woolrock but their importance as a source of these materials is not known. It has also been noted that in places the spoil banks are composed of a mixture of dolomite and clay. Locally such mixtures might have the chemical composition of woolrock or sub-woolrock but the feasibility of using them for making rock wool depends upon the solution of engineering problems involved in their utilization.

East St. Louis Area

(Madison and St. Clair Counties)

SUMMARY

The bedrock of the East St. Louis area is comprised of rocks of "Coal Measures" and Mississippian age. The former includes a number of thin limestone strata, some of which locally are woolrock or sub-woolrock. In the eastern and northern part of the area the "Coal Measures" limestones are deeply buried by glacial clay; in the southern part the caprocks of the Belleville (No. 6) and Blair (No. 5) coals outcrop in the Mississippi bluff east of East St. Louis, but are under a heavy overburden of bedrock and clay. Southeast of the bluffs at East St. Louis, the "Coal Measures" limestones may locally occur below a sufficiently thin overburden to be stripped, as near Millstadt where the caprock of coal No. 6 offers possibilities for development by this method. In general where the overburden is heavy, subsurface mining of the thicker limestone caprocks with or without the associated coals may be possible locally.

South of Dupo a 9-foot bed of impure Mississippian limestone crops out under very heavy overburden in an abandoned "cement rock" mine. A sample from this mine was a sub-woolrock.

Prospecting by drilling is necessary to evaluate the feasibility of exploiting the limestones of the East St. Louis area.

INTRODUCTION

The East St. Louis area (Fig. 12) lies in the vicinity of that city and comprises parts of Madison and St. Clair counties. The bedrock is of lower Mississippian and Pennsylvanian ("Coal Measures") age, the former underlying a considerable part of the region around Alton, Dupo and Columbia. In general the Mississippian rocks are pure limestones, low in alumina and silica, although locally impure layers may be present; they are, therefore, as a whole not natural woolrocks. At one place a bed of "cement rock" is a sub-woolrock.

"COAL MEASURES" ROCKS

The "Coal Measures" rocks are commonly deeply buried by clay and silt and usually are not exposed except along streams and in the Mississippi bluff northwest of Belleville. The limestone beds of the "Coal Measures" offer the most promise as rock wool making materials. All vary greatly in thickness and character and although only two of these beds, the caprocks of the Blair (No. 5) and Belleville (No. 6) coals, are known to be woolrock locally, it is possible that exploration and testing may reveal other similar beds.

The general sequence of the "Coal Measures" strata exposed in the East St. Louis area is as follows:

Generalized section of beds exposed in East St. Louis area[28]

		Thickness *Feet*
8.	Limestone (Shoal Creek), outcrops prominent north of O'Fallon.	2–5
	Shale and sandstone, used for clay products near French Village	8–25
7.	Limestone (Collinsville), sandy	2–4
	Silty shale, used for clay products near French Village	35±
	Shale and limestone, interbedded	2–3
	Coal (No. 8)	0–¼
	Shale, sandy shale, and clay, including red and green shale in basal portion	8–25
6.	Limestone (Piasa or Bankston Forks)	0–5
	Clay	4–5
	Sandstone, calcareous; best developed in the vicinity of Belleville; exposed in Workhouse quarry at Belleville	6–8
5.	Limestone (Jamestown)	0–3
	Coal (Jamestown), best developed in the vicinity of Bethalto	¼–2
4.	Limestone (Brereton or caprock of coal No. 6)	0–10
	Shale	1–2
	Coal, Belleville (No. 6)	6±
	Clay	2
3.	Limestone (St. David)	0–6
	Shale and clay	5–15
2.	Limestone (Hanover)	4–5
	Shale with a thin limestone	2
	Coal, Blair (No. 5)	½–3½
	Shale and sandstone	50–60
	Coal (No. 2)	0–2½
	Clay	2–3
1.	Limestone (Seahorne)	0–3
	Clay (Cheltenham), used for clay products at Alton	25–30

[28] Wanless, H. R., personal communication.

DESCRIPTION OF OUTCROPS SAMPLED

Because the "Coal Measures" limestones are commonly thin, only those limestones closely associated with workable coals and therefore, possibly mineable with the coals were sampled, with one exception.

The caprock of coal No. 5 is exposed in the entry to an old mine a short distance south of the present Old Hickory mine operating in coal No. 6 at the center of the W. ½ NW. ¼ sec. 3, T. 1 N., R. 9 W., in the bluff of Mississippi River. The section exposed between coals No. 5 and No. 6 is as follows:

Geologic section near Old Hickory mine

		Thickness *Feet*
10.	Coal, Herrin (No. 6)	
9.	Clay	2±
8.	Limestone, dense, gray, fine grained	2½
7.	Limestone, as above, but in irregular beds with clay partings ¼ to 1 inch thick	3½
6.	Covered	10–15
5.	Shale, gray	1–2
4.	Limestone, buff, earthy, weathered	4–5
3.	Shale, gray	1
2.	Limestone, buff, soft, weathered	¾–1
1.	Coal, Blair (No. 5)	

Sample *NF-85* was taken from bed No. 4, the caprock of the Blair coal. Sample *NF-84* was secured from beds Nos. 7 and 8. Sample *NF-85* proved to be woolrock (pp. 163, 166), and *NF-84* sub-woolrock (p. 174). A mixture whose chemical composition lies within the composition limits of woolrock could be obtained by adding to Sample *NF-84* shale from some of the associated shale beds. Analyses are given in Table 1 (p. 59).

The caprock of coal No. 6 was sampled at two mines. At the Signal Hill mine in the SW. ¼ SW. ¼ SE. ¼ sec. 26, T. 2 N., R. 9 W., the caprock was comprised of 3 layers (1) a lower dark gray bed 15 to 18 inches thick, (2) a middle shaly, gray and black fossiliferous beds 3½ feet thick, and (3) an upper dense, dark gray stratum 1½ feet thick. Sample *NF-82* was taken from the middle and uppermost beds but was too low in carbonates to fall within the composition limits of woolrock or sub-woolrock. Sample *NF-83* was obtained from the lower bed and was a woolrock (pp. 163, 166).

The caprock of coal No. 6 was also sampled at the Gunlock mines in the NE. ¼ NW. ¼ NE. ¼ sec. 24, T. 2 N., R. 9 W. Sample *NF-80* taken from a 4½ foot exposure in the mine entry was too high in carbonates to be a sub-woolrock, although its CO_2 content lies very close to the upper CO_2 limit for sub-woolrock.

SIGNIFICANCE OF OUTCROP DATA

The foregoing and other data indicate that locally the caprocks of the Blair (No. 5) and Belleville (No. 6) coals are woolrocks, but that these beds vary greatly in composition from place to place. None of the outcrops sampled are susceptible of economical development except by subsurface mining, nor is it probable that in the vicinity of the outcrops extensive areas will be found underlain by "Coal Measures" limestone at an average depth of less than 30 feet.

THICKNESS AND DEPTH OF "COAL MEASURES" LIMESTONES IN THE EAST ST. LOUIS AREA

The thicknesses of the various "Coal Measures" limestones are notably variable. The common range is shown in the "General sequence of beds" (p. 84). The depth of the beds below the surface at any given place depends on the surface elevation and the relation of the site to the structure of the bedrock. As all the "Coal Measures" limestones in the East St. Louis area lie a relatively short distance above or below coal No. 6, this coal is used in the table below as a key horizon from which the depth to the position of any given bed can be estimated. It should be remembered, however, that not all the limestones and associated beds are everywhere present.

Approximate depth to coal No. 6[29]

At or near	Depth *Feet*
Belleville	110–155
Collinsville	165–190
Edwardsville	130–215
Glen Carbon	95–175
Marysville	240
O'Fallon	200

DEVELOPMENT CONSIDERATIONS

Where heavy overburden covers the "Coal Measures" limestones, as it does throughout much of the area, it appears that subsurface mining must be resorted to if these beds are to be exploited. The Blair coal and its caprock, and the Belleville coal, its caprock, and the limestone under the floor clay might be mined as units where the limestones are comparatively thick and are woolrocks or sub-woolrocks. The Blair coal is not of mineable thickness at many places. Much of the available coal No. 6 has been mined out in the area, particularly in the vicinity of the towns listed above; the feasibility of attempting to recover the limestones where they are woolrocks or sub-woolrocks in such mined out tracts is questionable.

[29] Kay, F. H., Coal Resources of District VII, Illinois State Geol. Survey Coop. Mining Investigations Bull. 11, 1915, pp. 103 and 156, 1922.

The possibilities for finding areas where the limestones may be stripped are best near their line of outcrop, (Fig. 12). Conditions appear favorable for the occurrence of such areas south and southwest of Belleville, particularly in the vicinity of Millstadt. The Fisher Coal Company has operated a strip mine in sec. 12, T. 1 S., R. 9 W., about 3 miles east of Millstadt, in which the caprock of coal No. 6 was present, and numerous borings in the vicinity of the town also record the caprock. The possibilities of stripping coal No. 6 in this region are discussed in other Survey reports[30] from which data regarding the caprock of the coal may be deduced because of the close association of the two beds.

Borings in the Millstadt region show that the caprock of coal No. 6 varies in thickness from a few inches to a maximum of 14 feet, with thicknesses of 3 to 6 feet common. The depth of the caprock below the surface varies from a few feet to a recorded maximum of 58 feet and averages about 35 feet. At many places borings did not record limestone and presumably the caprock is absent. This is due in some places to erosion of the limestone, but at other places the stone appears not to have been deposited or to have been eroded before the deposition of the bedrock strata which normally overlie it.

A number of records report one to three additional limestone strata above the immediate limestone caprock of the coal. These upper limestones are separated by shale layers one to 14 feet thick. The limestones themselves range from one to 10 feet thick but are usually less than 6 feet thick. Some of these limestones doubtless correlate with the limestone beds shown above coal No. 6 in the "General Sequence" (p. 84), but the information available is in general insufficient to make such correlations with certainty.

No data are at hand regarding the chemical composition of the caprock in the Millstadt area but in the Freeburg area (p. 28) it is locally a woolrock or sub-woolrock and it may have a similar composition in this area.

In order to evaluate the possibilities of developing an area of "Coal Measures" limestone for rock wool, prospecting and testing must be detailed and thorough and must take into consideration (1) the "patchy" distribution and thickness variations of the limestone, (2) the variation in chemical composition, (3) thickness of overburden, (4) the possible existence of more than one usable bed in a given area, (5) the possibility of using two or more limestone beds, separated by a thin layer of clay, together with the clay for making rock wool, and (6) the feasibility of the joint recovery of the limestone with an associated coal. (See also "Development considerations," Duquoin area, page 27).

---

[30] Culver, H. E., Preliminary report on coal stripping possibilities in Illinois; Illinois State Geol. Survey Coop. Mining Series Bull. 28, 1925, pp. 43-45.
Cady, G. H., Coal stripping possibilities in southern and southwestern Illinois; Illinois State Geol. Survey Coop. Mining Series Bull. 31, 1927, pp. 46-47.

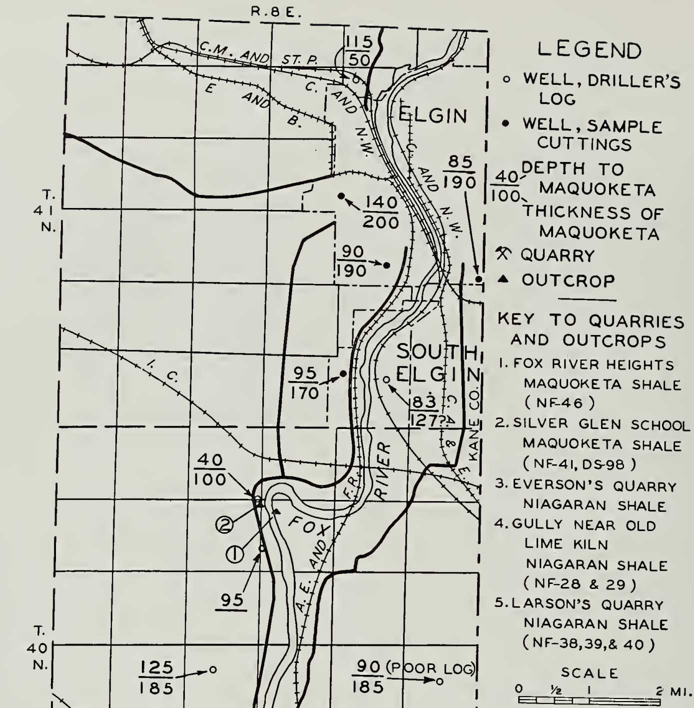


Fig. 13. Map of Elgin-Aurora area showing the locations of outcrops and quarries described, the locations where samples were obtained, and the depth to and thickness of the Maquoketa formation as known from well records.

LOWER MISSISSIPPIAN ROCKS

GENERAL DESCRIPTION

Only one outcrop of Mississippian rock, which appeared to be sufficiently impure to be a woolrock or sub-woolrock, was noted in the East St. Louis area, namely, 9 feet of argillaceous Warsaw limestone exposed in a long-abandoned "cement rock" mine in the south wall of Cement Hollow, NE.¼ SW. ¼ NW. ¼ sec. 34, T. 1 N., R. 10 W., south of Dupo. Sample *NF-192* was obtained from the upper 7 feet 9 inches of rock exposed in the old mine; the lower 15 inches of stone was water covered. The sample was a sub-woolrock requiring the addition of shale or clay to yield a mixture whose chemical composition lies within the composition limits of woolrock. Clay is available from material capping the ridges in the vicinity of the mine and shale from thin beds associated with the limestone or from deposits near Millstadt or Belleville.

The extent of the "cement rock" bed is not known. The bed dips below the level of Cement Hollow east of the old mine and in a small quarry about 100 feet west of the mine entry it appears to be represented by a series of alternating shale and relatively pure limestone beds.

The "cement rock" stratum lies at the base of a hill about 125 feet high and would consequently require subsurface mining.

As the old mine was partly water filled when visited, its extent could not be determined. Thorough exploration of the deposit, probably by core drilling, and testing of samples should precede any attempts to work the "cement rock" bed.

Elgin-Aurora Area
(Kane County)

SUMMARY

Two shale formations, the Maquoketa and the Niagaran shale crop out in the Elgin-Aurora area, and samples of both have been found to be woolrock. Neither formation is known to occur in areas favorable for large scale open-pit mining. Evaluation of the feasibility of subsurface mining depends on the results of exploratory test boring and testing of samples thus obtained and also on economic factors.

INTRODUCTION

The Elgin-Aurora area (Fig. 13) lies along Fox River in Kane County between the two towns from which the area is named, and occurs in a region where glacial deposits deeply bury the bedrock. Outcrops are restricted to the lower slopes of the valley wall of the river. The sequence of bedrock formations exposed is as follows:

	Thickness *Feet*
Silurian system	
Niagaran dolomite (including Niagaran shale)	40–50
Kankakee dolomite	30–40
Ordovician system	
Maquoketa shale	15+

Samples from the Maquoketa and the Niagaran shales were found to be woolrocks.

MAQUOKETA SHALE

DESCRIPTION OF OUTCROPS

The Maquoketa shale crops out in the Elgin-Aurora area only in a limited tract about 2 miles southwest of South Elgin. The best exposures noted occurred (1) in the river bank in the SE. 1/4 NW. 1/4 NW. 1/4 sec. 10, T. 40 N., R. 8 E., about 300 feet south of the bathing beach at Fox River Heights; and (2) in the NE. cor. sec. 9 of the same township in a gully immediately south of Silver Glen school.

The first exposure reveals a maximum of 6½ feet of thin bedded greenish-gray upper Maquoketa shale containing flat irregular fragments of limestone. Lesser exposures are found at intervals in the river bank south for about 750 feet. The presence of the Kankakee dolomite in the river bluff is indicated by large blocks of this rock at the water's edge, but at no place was its contact with the underlying Maquoketa shale observed. The bedrock at this place is generally overlain by glacial clay and gravel which together with the Kankakee dolomite constitutes an overburden on the Maquoketa shale estimated to be 50–70 feet thick.

Sample *NF-46* was taken from the 6½ foot outcrop of shale and was found to be a woolrock (pp. 163, 166). The analysis of this sample is given in Table 1 (p. 60).

The outcrop near Silver Glen school in the NE. corner of sec. 9, T. 40 N., R. 8 E., reveals the following:

Geologic section near Silver Glen School

	Thickness *Feet*
Pleistocene system	
Clay and gravel	0–10
Silurian system	
Kankakee dolomite, brown, porous, in beds 1 to 3 inches thick	12±
Ordovician system	
Maquoketa shale, mostly concealed; exposed shale is gray-green with thin irregular limestone fragments	15+
Concealed	

Sample *NF-41* was taken from the Kankakee dolomite exposed in the above section and *DS-98* from a 5-foot outcrop of the Maquoketa shale immediately below the dolomite. Their analyses are given in Table 1. Sample *DS-98* was found to be a calcareous shale, very nearly a sub-woolrock, requiring the addition of limestone or dolomite to yield a mixture whose chemical composition lies within the composition limits of woolrock. Combination of the Kankakee dolomite with the shale could effect the desired mixture.

STRUCTURE OF MAQUOKETA SHALE AT OUTCROPS

The outcrops of the Maquoketa shale mentioned result from the erosion by Fox River of a slight arch in the bedrock strata. Because of this the shale disappears below the surface about ½ mile above and below the outcrops previously described.

POSSIBILITY OF DEVELOPMENT OF OUTCROPS

The limited outcrops of Maquoketa shale furnish insufficient information to permit a thorough evaluation of their development possibilities either with respect to the chemical character of the deposits as a whole or of the extent of the area where the shale may be economically quarried by open pit methods. Such data can be obtained only by core drilling and extensive testing of samples.

It appears that the chances for open pit operations on the east side of the river are not promising. The river bluff rises sharply from the water's edge and operations begun at the outcrop of the shale would soon encounter a dolomite and clay and gravel overburden 30 feet or more thick which would increase rapidly as the deposit was worked back into the bluff. As the shale deposit occurs low in the bluff, open pit operations would be in danger of flooding by the Fox River at times of high water. Further, the river bluff in this region is the site of many summer homes and the land therefore is probably comparatively high priced. The exposure of shale is an airline mile from the nearest railroad, the Aurora, Elgin, and Fox River Railroad.

The outcrop near the Silver Glen school occurs in the frontal slope of a small terrace lying between the flat of Fox River and the bluffs to the west. Immediately south of the outcrop an area 150–300 feet wide and ¼ to ⅓ mile in length with an average of 10–20 feet of shale above the level of Fox River might be quarriable by open pit methods but conditions in this tract can be determined only by test drilling. It cannot be considered a highly desirable quarry site, however, as it is about ½ mile airline to the nearest railroad (the Illinois Central), is bordered on the west by an important concrete highway which might be made insecure by quarrying, and lies in a region largely given over to resorts or country homes.

GENERAL DESCRIPTION OF THE MAQUOKETA FORMATION[31]

The Maquoketa formation in this area as known from sub-surface studies varies considerably from place to place but in general may be divided into four units from the bottom upward as follows: (1) shale, (2) shale and dolomite, (3) dolomite, and (4) shale and dolomite.

The basal shale member (1) is fairly persistent. The shale is brown and locally contains a few interbedded layers of dolomite which are probably lenticular and, therefore, of variable thickness from place to place. The thickness of this member varies but in general is probably between 15 and 45 feet.

The lower shale and dolomite member (2) is also a fairly persistent unit. The shale is gray or brown; the dolomite is brownish-gray and argillaceous. Locally limestone beds are present. The limestone and dolomite beds range in thickness from a few inches to 5 feet or more and are usually cherty. The total thickness of the limestone and dolomite member varies considerably but in general is probably between 50 and 100 feet.

The dolomite member (3) is not everywhere present, but where well developed is a coarse grained, speckled, locally cherty dolomite ranging from 10 to 20 feet in thickness.

The upper shale and dolomite member (4) ranges from a few inches to 60 feet in thickness and in some places is absent due to the erosion of the top of the Maquoketa formation before the overlying Kankakee dolomite was deposited. Where typically developed the member is characterized by green or greenish shales, although gray shales are also present, and pink shale occurs at the top where pre-Silurian erosion has not taken place. The dolomite beds are green to gray in color and from a few inches to 5 feet in thickness. The exposures at Fox River Heights and Silver Glen school belong to this member.

DEPTH AND THICKNESS OF MAQUOKETA FORMATION

In figure 13 the depth and thickness of the Maquoketa formation is shown at those points where well records afford such data. In general the formation dips southeast or east from Elgin but so far as depth below the surface is concerned, the effects of the dip are compensated in many places by differences in the surface elevations of the sites where the wells were drilled.

DEVELOPMENT CONSIDERATIONS

Foregoing data suggest that the Maquoketa formation has possibilities as a source of woolrock. Because of the heavy overburden which covers the formation throughout most of the area, and the limited character of the outcrops, exploitation of the shale by sub-surface mining at points favorably

[31] The writers are indebted to Mr. L. E. Workman, Geologist-in-charge of the sub-surface studies, Illinois Geological Survey, for much of the information regarding the subsurface character of the Maquoketa and Niagaran formations.

located with reference to transportation and markets is probably the most feasible means of development. The two dolomite and shale members (2) and (4) appear to offer the most promise for the occurrence of woolrock in the form of dolomitic or calcareous shale or of strata comprised of interbedded shale and thin limestone and dolomite layers. The basal shale may also offer possibilities though little is known in detail regarding its composition.

Definite evaluation of the worth of the Maquoketa formation as a source of woolrock can be determined only after additional studies involving core drilling, testing of samples, and consideration of engineering and economic features.

NIAGARAN SHALE

DESCRIPTION OF OUTCROPS

The Niagaran shale is known to crop out at three places in the Elgin-Aurora area. It seems probable that the outcrops are all the same bed, although they differ somewhat in character, and that this bed occurs roughly 100 feet above the top of the Maquoketa shale. The data available indicate that no other shale beds are present in the Niagaran formation in this area.

The first of the outcrops of the Niagaran shale occurs in the small gully in the east valley wall of Fox River, south of Batavia, in the NW. ¼ NE. ¼ NE. ¼ sec. 27, T. 39 N., R. 8 E., near the ruins of an old lime kiln. The outcrop lies between the concrete road and the river and exposes the following beds:

Exposure in the NE. ¼ sec. 27, T. 39 N., R. 8 E.

	Thickness *Feet*
Pleistocene system	
4. Soil and clay	3
Silurian system	
Niagaran formation	
3. Dolomite, thin bedded, slabby, brown	4½
2. Shale, yellow and gray-green, with thin, argillaceous limestone layers, 1 to 5 inches thick	4½
1. Shale, purple, blocky	3+

Sample *NF-28* from bed 3 is a sub-woolrock, and *NF-29* from beds 1 and 2 a woolrock (pp. 162, 165). Analyses of these samples are given in Table 1.

Another exposure across the river from the above outcrop, in Larson's quarry in the NW. ¼ NE. ¼ SW. ¼ sec. 27, T. 39 N., R. 8 E., consists of the following:

Exposure in quarry in SW. ¼ sec. 27, T. 39 N., R. 8 E.

	Thickness *Feet*
Pleistocene system	
4. Soil and clay	3
Silurian system	
Niagaran formation	
3. Dolomite, gray, brown and pink, in thin beds with mostly green shale partings ¼ to ½ inch thick	9
2. Shale, green at top grading to red below, locally gray	2
1. Dolomite, mottled pink and green, locally thin shale partings	7+
Covered	

Sample *NF-38* was taken from bed 3; *NF-39* from bed 2 and *NF-40* from bed 1. Analyses of these samples are given in Table 1. Sample *NF-39* is a sub-woolrock requiring the addition of dolomite or limestone, the former available from the over or underlying strata, samples *NF-38* and *NF-40* (p. 174).

The third exposure occurs in Everson's quarry in the SE. ¼ SE. ¼ SW. ¼ sec. 15, T. 39 N., R. 8 E., where about 2½ feet of buff shale occurs interbedded with dolomite.

DEVELOPMENT CONSIDERATIONS

Outcrops.—The outcrops of the Niagaran shale demonstrate the local existence of a shale member in the Niagaran formation which is woolrock or sub-woolrock in some places. They suggest that the shale is variable in thickness, usually less than 3 feet.

Of the outcrops observed, only the one in the NE. ¼ sec. 27, T. 39 N., R. 8 E., suggests the presence of a deposit thick enough to be of possible economic value and its importance is questionable. Seven and one-half feet of shale was noted at this outcrop but the base of the shale bed was covered so that its total thickness is not known. The outcrop occurs in a narrow terrace between Fox River and a concrete road to the east; its overburden consists of both dolomite bedrock and unconsolidated material which increases eastward from the outcrop. Open pit mining does not appear feasible but subsurface mining may be possible in the general vicinity. Thorough test drilling of the deposit to furnish samples for testing and to provide data regarding variations in the thickness and distribution of the shale is desirable before development is undertaken. The Chicago, Burlington & Quincy Railroad is about 1/10 mile east of the outcrop.

General.—The data at hand regarding the Niagaran shale do not indicate it to be an important source of woolrock. The shale is variable laterally within comparatively short distances, both in thickness and in physical and chemical character, and is inferior in the first respect and probably in the second to the Maquoketa formation which lies below the Silurian formations. There is no definite information, except that furnished by the outcrops described, regarding the thickness of the Niagaran shale. Its lateral extent is also problematical.

As the Niagaran shale is overlain by a thick dolomite formation which is resistant to erosion and which protects the underlying shale, it is doubtful if areas of any considerable size will be found where the shale can be mined by open pit methods. The feasibility of subsurface mining is uncertain.

Because of the probable variability of the shale, thorough exploration, by drilling and testing of samples, of any deposit seems imperative before development is undertaken.

Kankakee Area[32]

SUMMARY

Samples of "Niagaran" dolomite obtained from outcrops near Manteno and Aroma Park have been found to be woolrock or sub-woolrock. Data available from outcrops are insufficient to demonstrate the existence of workable deposits of woolrock or sub-woolrock. Prospecting may well reveal such deposits.

INTRODUCTION

Dolomite lies at a comparatively shallow depth at many places in the vicinity of Kankakee. The nature of the "Niagaran" dolomite formation which underlies the surficial material is not known in detail because of lack of adequate outcrops or borings. East of a north-south line through Kankakee impure argillaceous dolomite has been observed at several places but west of this line such strata have not been observed. Quarries at Kankakee and Lehigh and outcrops along Kankakee River northwest of Kankakee usually contain but small amounts of argillaceous or siliceous materials. Near Manteno two exposures of impure dolomite are known and also one of coralline dolomite about 1½ miles south of the town in the SE. ¼ sec. 28, T. 32 N., R. 12 E. Near Aroma Park two exposures of impure dolomite have been observed.

DESCRIPTION OF OUTCROPS SAMPLED

OUTCROPS NEAR MANTENO

Thirty-three inches of impure mostly gray dolomite is exposed along a small creek just north of an east-west road a little north of the center of

[32] The writers are indebted to Dr. G. E. Ekblaw and Mr. L. E. Workman of the Survey staff for their assistance in matters pertaining to the geology of this area.

the south line of sec. 15, T. 32 N., R. 12 E., at the east edge of Manteno. The dolomite occurs in thin beds 1 to 4 inches thick. Sample *NF-154* was taken from this outcrop and found to be a woolrock (Table 1, p. 61). The exposure is overlain by about 6 feet of pebbly clay.

In the SE. ¼ NE. ¼ sec. 20, T. 32 N., R. 12 E., a small quarry located in a broad flat hill exposes 15 feet of fine grained gray dolomite in beds 1 to 12 inches thick. The middle 5 feet is in beds 1 to 3 inches thick and is somewhat more argillaceous than the over- and underlying stone. Overburden reaches a maximum of five feet of sandy loam. The analysis of Sample *L-107* (Table 1) taken from the 15 feet of rock exposed[33] shows the rock to be a sub-woolrock.

OUTCROPS NEAR AROMA PARK

Impure Niagaran dolomite is exposed in places along Iroquois River for several miles above its mouth and is also reported to occur, together with purer dolomite, in a quarry at the north edge of the town of Aroma Park. In the SE. ¼ sec. 22, T. 30 N., R. 13 W., the rock is covered by about 15 feet of sand and is exposed at low water in the river bank at a number of places, particularly in the west bank in the SW. ¼ SE. ¼ of the section.

The best outcrop noted occurs in the east river bank in the SE. ¼ SW. ¼ sec. 28, T. 30 N., R. 13 W., where a few inches to 5½ feet of gray dolomite, in beds ½ to 5 inches thick, is exposed for a distance of about 1000 feet. The outcrop was examined when the river was in flood and it is probable that at average water stages the outcrop is considerably more extensive. The overburden on the stone is probably sand, some of it water bearing, and pebbly clay which together average about 15 feet thick in the region adjacent to the outcrop.

Sample *NF-95* was taken from the above outcrop and has been shown by tests (Table 1) to be a sub-woolrock, requiring the addition of clay, shale, or sandstone to yield a mixture whose chemical composition lies within the composition limits of woolrock (p. 174).

DEVELOPMENT CONSIDERATIONS

Test drilling and testing of samples thus obtained are necessary to evaluate the rock wool making possibilities of the impure dolomite deposits of the Kankakee area. The results of such work cannot be anticipated, but conditions seem favorable for the existence of deposits of sub-woolrock and possibly woolrock which can be developed by open pit methods in the general vicinity of the outcrops described, and possibly elsewhere.

Clayey or sandy materials for admixture with sub-woolrocks may possibly be obtained from the overburden on the dolomite deposits. In the Aroma Park tract pebbly clay is available in large amounts from the broad

[33] Illinois State Geol. Survey Bull. 46, pp. 131 and 320, 1925.

hills in secs. 3, 4, 5, and 6, T. 29 N., R. 13 W., and in sec. 25, T. 30 N., R. 13 W., and sec. 30, T. 30 N., R. 12 W.

No shale deposits are known close by but large quantities of this material are available from coal mining operations about 25 to 35 miles northwest in southeastern Grundy County. Other shale deposits are exposed in the north valley wall of Kankakee River in secs. 27 and 36, T. 32 N., R. 10 E., and also along Horse Creek near the center of the east line of sec. 24, T. 32 N., R. 9 E. Sandstone is available locally in Grundy and eastern LaSalle counties.

The deposits at Manteno are about ¼ and 1¼ miles respectively from the Illinois Central Railroad. Those along Iroquois River are one to three miles from the Cleveland, Cincinnati, Chicago and St. Louis Railroad and 2½ miles from the Illinois Central Railroad at the nearest point.

Lemont Area

(Cook and DuPage counties)

NIAGARAN DOLOMITE NEAR LEMONT

SUMMARY

At the east limits of Lemont, 20–25 feet of very cherty Niagaran (Waukesha) dolomite is exposed in old quarries in the south wall of the DesPlaines valley. Samples of the dolomite have been found to be woolrock and sub-woolrock. Exploitation may be feasible by subsurface mining and over limited areas by open pit mining. Rail and water transportation are close by.

DESCRIPTION OF OUTCROPS SAMPLED

The following strata are exposed in an old quarry located in the south bluff of DesPlaines River in the NW. ¼ NE. ¼ SW. ¼ sec. 21, T. 37 N., R. 11 E., just east of the city limits of Lemont:

	Thickness *Feet*
Pleistocene system	
4. Clay, pebbly and silty	0–25+
Silurian system	
Niagaran series	
Waukesha formation	
3. Dolomite, brownish-gray, very cherty, fractured, weathered (Sample *DX-5*)	10–12
2. Dolomite, gray, cherty, with many bands of white chert (Sample *DX-4*)	12–15
Joliet formation	
1. Dolomite, chert free, in beds 1 to 3 feet thick	10+
Covered	

Sample *DX-4* from bed No. 2 was found to be sub-woolrock and Sample *DX-5* from bed No. 3 a woolrock (Table 1, p. 63). A combination of these two samples in amounts proportionate to their exposed thicknesses gave rock wool experimentally (pp. 163, 166, 174). A mixture whose chemical composition lies within the composition limits of woolrock may also be obtained by adding clay, shale, or sandstone to *DX-4*.

The dolomite sampled near Lemont comprises a bedrock hill which has a more or less irregular surface and rises to a maximum of about 50 feet above the level of the flat of DesPlaines River. It does not constitute a distinct topographic feature, however, as it is obscured by glacial clay and gravel except in the bluffs of the river. Exposures occur in the south bluff from Lemont east to the center of sec. 21, a distance of about ½ mile.

DEVELOPMENT CONSIDERATIONS

The thickness of the Waukesha formation in the vicinity of Lemont is characteristically about 30 feet[34] and it seems likely that the outcrop sampled comprises the major part of the formation. The formation is typically cherty throughout but the amount of chert is variable.

The overburden at the outcrop consists of glacial till whose thickness ranges from a few inches to about 25 feet. The thickness of till together with associated gravel doubtless increases back into the bluff. A comparatively small amount of Waukesha dolomite with less than 25 feet overburden probably could be obtained by open pit methods.

The possibility of subsurface mining cannot be evaluated from the data at hand. It is doubtful whether some of the woolrock strata, if left for a roof, would be satisfactory because of their thin bedded character. There are no data to show whether or not other bedrock formations suitable for a roof are present back from the bluffs.

Prospecting by test drilling should be thorough in order that detailed data may be obtained regarding the extent of the Waukesha dolomite and the character and thickness of overburden. These data will serve as a basis for determining the best method of producing the stone. Samples of the Waukesha dolomite should be secured from the borings and tested to determine the chemical composition of the stone. In this connection it should be noted that the large amount of chert in the Waukesha is of major importance in making it a woolrock. Prospecting should, therefore, be designed to show whether or not the highly cherty character of the Waukesha formation persists back from the outcrop.

In the event that the rock wool making properties of the Waukesha dolomite can be improved by the admixture of small amounts of argillaceous or siliceous material, some of the overlying glacial till may possibly be added. If shale or bedrock clay is desired, it may be obtained from old coal mine dumps or the shale overburden removed in connection with strip mining near Coal City, an airline distance of about 30 miles southwest of Lemont or from

[34] Workman, L. E., Personal communication.

clay pits near Morris (Goose Lake) in Grundy County. The nearest sandstone deposits located on a railroad occur in the vicinity of Morris.

The Chicago and Alton and the Chicago and Joliet Electric railroads traverse the flat at the foot of the bluff, and the Illinois Waterway is about one-half mile north of the bluff.

Investigation of the north bluff of Illinois River northeast of Lemont may reveal cherty Waukesha dolomite in that area but mostly under thick overburden.

Oregon Area
(Ogle County)

SHAKOPEE FORMATION NEAR OREGON

SUMMARY

A 24-foot outcrop of the Shakopee formation occurs west of Oregon where it is comprised of interbedded dolomite, sandy dolomite, and shale. The exposure as a whole may be a sub-woolrock. Clay or sandstone for mixing with the Shakopee materials is available from the overburden. The extent of the area which may be quarried is not known, but it is probably small. Railroad transportation is close at hand.

GENERAL DESCRIPTION

The Shakopee formation crops out in the Oregon area only along Gale Creek about ¼ mile northwest of the center of sec. 6, T. 23 N., R. 10 E., in a small quarry at the intersection of the creek and a road three miles west of Oregon. The outcrop is the result of the erosion of the crest of a narrow plunging anticline. Almost 24 feet of rock is exposed in beds varying from ½ inch to 3 feet thick, including dolomite, sandy dolomite, argillaceous dolomite, clay, shale, dolomitic shale, and dolomitic sandstone. Many of the beds are lenticular. Tabulated data concerning the various kinds of rock exposed are given below:

Kind of rock	No. of beds	Total thickness	Range in thickness of beds	Per cent of total exposure
Sandy dolomite	13	13′ 9″	2–36″	58
Dolomite	3	1′ 10″	5–12″	8
Argillaceous dolomite	2	1′ 1″	2–11″	5
Dolomitic sandstone	1	1′ 11″		8
Shale and clay...........	16	5′ 0″	½–11″	21
	35	23′ 7″		100

Sample *NF-124* was taken from 5 beds of sandy dolomite totaling 6 feet in thickness in the upper part of the exposure, and *NF-125* from 3 beds of shale comprising a thickness of 2 feet in the lower portion of the outcrop. Sample *NF-124* proved to be sub-woolrock and *NF-125* to be woolrock (Table 1, p. 63; also pp. 164, 167).

DEVELOPMENT CONSIDERATIONS

In view of the fact that the deposit consists of many thin and lenticular beds, it is probably impossible to develop it economically except as a unit. It is thought that the chemical composition of the outcrop as a whole is probably that of a sub-woolrock. Little is known regarding the character of deeper unexposed portions of the Shakopee formation, but it seems likely that the formation as a whole will become less sandy and shaly with depth.

Overburden on the deposit consists of 2 to 3 feet of clay at the outcrop but sandstone of the St. Peter formation also probably overlies the dolomite a short distance back from the outcrop. The sandstone or the clay, when mixed with the Shakopee sediments in the proper proportion will yield a mixture whose chemical composition lies within the composition limits of woolrock.

The extent of the area underlain at a shallow depth by the Shakopee formation is not known, but is probably comparatively small. The outcrop occurs along the west side of a roughly north-south ridge which is cut by the Chicago, Burlington and Quincy Railroad, thus dividing the most promising area for open pit quarrying into two parts. Subsurface mining may be feasible locally where the St. Peter formation is thick enough to make a good roof.

Thorough careful prospecting by test drilling and comprehensive testing of samples are required to evaluate the worth of this deposit as a source of rock wool making materials.

Pontiac Area
(Livingston County)

SHALY LIMESTONE BELOW THE PONTIAC LIMESTONE AT PONTIAC

SUMMARY

Results of chemical analyses of samples of a shaly limestone lying below the limestone which crops out commonly in the vicinity of Pontiac, show that the shaly limestone is locally a woolrock or a sub-woolrock. Detailed exploration is needed to evaluate the possibility of exploiting the shaly limestone.

GENERAL DESCRIPTION

Samples of a thin bedded, blue-gray, shaly limestone occurring below the limestone[35] (Pontiac limestone) commonly exposed in the vicinity of Pontiac are shown by several chemical analyses to be either woolrock or a sub-woolrock. The shaly limestone was observed only in the floor of a quarry in the SW. 1/4 NE. 1/4 sec. 16, T. 28 N., R. 5 E., where a little over a foot of the rock is visible. The bed was penetrated to a depth of 4 feet in a boring

[35] Lamar, J. E., Limestone resources of the Pontiac-Fairbury region: Illinois State Geol. Survey Report of Investigations 17, 1929.

near this quarry but no other data are available regarding its thickness. However, test borings may reveal a workable thickness of this shaly limestone.

The chemical composition of the shaly limestone is shown in Table 1, (p. 63). Sample *P-4* and *DS-99* were taken from different places in the floor of the quarry and each represents 1 foot 2 inches of the shaly limestone. The analysis of sample *P-10*, taken from the quarry floor, was furnished by the owner of the quarry as was the analysis of *P-11* which is the result of tests on 4 feet of core from a boring which penetrated 4 feet into the shaly limestone.[36] *P-10* and *P-11* are woolrocks and *P-4* and *DS-99* sub-woolrocks.

The chemical analyses show marked lateral variation in the composition of the limestone and indicate that it is locally a calcareous shale. Probably the shaly limestone is usually most calcareous near its contact with the overlying limestone and the carbonate content probably decreases with depth. The upper shaly limestone beds are locally somewhat too high in carbonates to be woolrocks but by adding to them sandstone or possibly some of the deeper shale it seems likely that a suitable mixture could be obtained (p. 168).

DEVELOPMENT CONSIDERATIONS

The overburden on the shaly limestone consists of limestone from a few feet to 22 feet thick overlain by pebbly clay and soil from a few inches to about 25 feet thick. There are a number of places, however, where the clay and soil portion of the overburden is less than 10 feet thick over considerable tracts and exploration may likewise find areas where the limestone above the shale is also less than 10 feet thick or even absent.[37]

The potential value of the shaly limestone as a woolrock and the possibilities of exploiting it can be determined only by thorough test drilling and laboratory tests. Its extent is not known. In addition to the outcrop mentioned, however, the overlying Pontiac limestone is exposed in outcrops or quarries in the SE. ¼ sec. 9, S. ½ S. ½ sec. 15, NW. ¼ sec. 23, T. 28 N., R. 5 E., along the east side of the concrete road near the center of the east line sec. 25, T. 27 N., R. 4 E.; the NW. cor. sec. 23; NW. ¼ NE. ¼ sec. 1; NE. ¼ NE. ¼ sec. 12, T. 27 N., R. 5 E.; the NE. ¼ NW. ¼ sec. 7; SE. ¼ sec. 19, T. 27 N., R. 6 E.; and along the creek near the center sec. 16, T. 26 N., R. 6 E. Limestone is reported at depths of less than 20 feet in wells in the SW. ¼ SW. ¼ sec. 19, T. 27 N., R. 6 E., NE. cor. sec. 23, center east line sec. 16, and center S. ½, S. ½ sec. 5, T. 27 N., R. 5 E.[38] Exploration in these tracts may reveal shaly limestone or calcareous shale below the Pontiac limestone.

The Illinois Central, Chicago and Alton, and Wabash railroads intersect a short distance north of Pontiac and some one of these railroads is within a mile of most of the outcrops mentioned above.

---

[36] Lamar, Op. cit., pp. 13, 14, and 16.
[37] Idem.
[38] Lamar, Op. cit., pp. 17-22.

Valmeyer Area
(Monroe County)

SUMMARY

A sample from an 11-foot exposure of siliceous, cherty limestone occurring low in the bluff of Mississippi River, about ½ mile northeast of Valmeyer, was found to be a woolrock. Another sample obtained from a gravelly mixture of chert and limestone resulting from the weathering of a cherty limestone exposed in the Mississippi River bluff about two miles northeast of Valmeyer proved to be a sub-woolrock. Evaluation of the possibility of developing either deposit depends on the results of exploratory drilling but it seems probable that the first deposit can best be exploited by subsurface mining and the second by open pit operations.

INTRODUCTION

Two different types of material, which have been found to be potentially valuable for rock wool manufacture, were sampled near Valmeyer. Because of their dissimilarity they are discussed separately.

CHERTY, SILICEOUS LIMESTONE

Near the crushing plant of the Columbia Quarry Company about ½ mile northeast of Valmeyer in the NE. ¼ NW. ¼ SW. ¼ sec. 3, T. 3 S., R. 11 W., 11 feet of siliceous, cherty, dense, light buff limestone in beds 2 to 6 inches thick, is exposed over a limited area low in the bluff of Mississippi River. As the base of the bed was not observed, the thickness may exceed 11 feet. The geological age of the formation has not been definitely determined, but may be Decorah. The cherty limestone has a heavy limestone overburden, which in turn is overlain by clayey silt, averaging about 35 feet thick. Sample *NF-89* was taken from the outcrop of cherty limestone and has been found to be a woolrock (Table 1, p. 64; also pp. 164, 167).

The cherty limestone exposure occurs near the axis of an anticline which extends southeast from Valmeyer. The southwest side of the fold dips steeply to the southwest, the northeast flank lowers gradually to the northeast. Development, if undertaken on a large scale, will doubtless have to be carried out by subsurface mining. Test drilling and testing of samples thus obtained is recommended to determine the total thickness of the bed, its lateral variations and subsurface distribution.

The Columbia Quarry Company has a switch to the Missouri Pacific Railroad about ¼ mile to the west.

KEOKUK-BURLINGTON FORMATION

The Keokuk-Burlington formation is exposed locally about two miles northeast of Valmeyer in the lower and middle portions of the bluffs of Mississippi River for a distance of about a mile in sec. 35, T. 2 S., R. 11 W.

It is also present in the higher areas east and southeast of the same town and underlies a large part of an elongate tract about ½ mile wide between Valmeyer and Madonnaville. The Keokuk-Burlington formation where unweathered is normally a coarsely crystalline limestone containing numerous irregular beds of chert. The formation is about 100-125 feet thick. No samples of unweathered Keokuk-Burlington limestone were tested from the Valmeyer district, but parts of the formation may locally prove to be a sub-woolrock. The Keokuk-Burlington in the Valmeyer region, where weathered, is locally more or less broken down to a gravelly mass comprised of chert and limestone and a comparatively small amount of yellow or red iron-stained clay. Due to the removal of carbonates by weathering, the proportion of chert present in the weathered rock is greater than in the unweathered parent rock.

Sample *NF-90,* taken from the lower 35 feet of an exposure of about 100 feet of weathered Keokuk-Burlington in the SW. ¼ sec. 35, T. 2 S., R. 11 W., was found to be a sub-woolrock requiring the addition of shale or clay to yield a mixture whose chemical composition lies within the composition limits of woolrock (p. 174). Clay is available from the brown clayey silt which caps the river bluffs and averages about 35 feet thick and shale may be obtained from the Maquoketa formation which is about 80 feet thick and occurs mostly in grass covered slopes comprising the lower part of the bluffs in the SW. ¼ SW. ¼ sec. 35, and the SE.¼ SE. ¼ sec. 34, T. 2 S., R. 11 W., and along many of the creeks in the E. ½ sec. 3, T. 3 S., R. 11 W., near Valmeyer.

The distance to which the weathered phase of the Keokuk-Burlington extends back from its outcrop is not known and consequently the amount of weathered rock available is unknown. In view of the thickness of the formation, it appears that locally a good volume of this material may be obtained by working an open pit quarry having a face of considerable linear extent. However, exploration and testing of samples is needed to disclose accurate data regarding the extent, uniformity, and character of deposits. Such exploratory work will also give data on the character and rock wool making possibilities of the unweathered rock.

The Missouri Pacific Railroad passes the bluff outcrops of the weathered Keokuk-Burlington limestone about one mile to the west.

Deposits of Sub-Woolrock

WORKABLE DEPOSITS

Thornton Area
(Cook County)

NIAGARAN DOLOMITE AT THORNTON

SUMMARY

A sample from 40 feet of Niagaran dolomite exposed in the south face of an abandoned portion of the large Molding Brownell Company quarry at Thornton has been found to be sub-woolrock. The extent of the impure dolomite is not known.

GENERAL DESCRIPTION

The following section is exposed in the south face of an abandoned portion of Molding Brownell Company quarry in the SE. ¼ NW. ¼ SE. ¼ sec. 33, T. 36 N., R. 14 E.

Geologic section in south face Thornton quarry

		Thickness *Feet*
3.	Soil and gray clay, mixed by overcasting during stripping......	3±
2.	Clay, gray and pink, containing scattered pebbles..............	5–8±
1.	Dolomite, gray and brown, locally streaked with green; in places argillaceous and/or petroliferous......................	40+

Samples *NF-58* (Table 1, p. 63) was taken from the dolomite, bed No. 1. and was found to be a sub-woolrock requiring the addition of shale, clay, or sandstone. Sample *NF-57* (Table 1) was obtained from the pebbly clay, bed No. 2, overlying the dolomite, and may serve as a material for admixture with the dolomite (p. 174). No shale is close at hand but "Coal Measures" shale is available from the region around Wilmington in southwestern Will County, about 40 miles airline southwest of Thornton, where coal stripping operations remove shale as overburden from coal, and old mine dumps also afford large amounts of shale. Sandstone is available locally in western Grundy and eastern LaSalle County.

DEVELOPMENT CONSIDERATIONS

The extent of the impure dolomite exposed in the south end of the Thornton quarry is not known. The other parts of the Thornton quarry show no such impure rock and the area to the north, therefore, does not appear promising for continuations of the impure stone. Nevertheless, a small outcrop of Niagaran dolomite, reported to be impure, occurs on Thorn Creek in the S. ½ sec. 4, T. 35 N., R. 14 E., and it is possible that the general region between the quarry and this outcrop is underlain locally by dolomite roughly similar to that in the Thornton quarry.

The overburden on the dolomite is mainly sandy soil and pebbly clay.[39] The thickness of the overburden is known only within the town of Glenwood where wells encounter rock at depths between 32 and 80 feet with an average depth, in the 9 borings reported, of about 54 feet[40] and at the Thornton quarry where the overburden on the stone is about 10 to 15 feet. Elsewhere it is doubtless variable and probably thinnest in the valley flat of Thorn Creek. Sizeable valley flat areas, about ¼ mile wide, occur in the SW. ¼ NW. ¼ sec. 3, and the SE. ¼ sec. 4, T. 35 N., R. 14 E., in the vicinity of Glenwood.

The Niagaran dolomite varies notably in the Thornton region, both as to chemical composition and physical character; thorough prospecting is therefore desirable to obtain data regarding the extent, variations in character and thickness of the impure dolomite and the nature and thickness of the overburden.

The Chicago Terminal Railroad, the Baltimore and Ohio Railroad, and the Chicago and Eastern Illinois Railroad traverse the area.

Utica Area
(LaSalle County)

SHAKOPEE DOLOMITE NEAR UTICA

SUMMARY

The Shakopee dolomite crops out in the north bluff of Illinois valley for a distance of about 2 miles and is exposed in quarries in the valley floor near Utica. Outcrops of 60± feet of the formation, which has a total thickness of about 185 feet, occur at a number of places in the bluff. The dolomite is highly variable in character. Some samples have been found to be sub-woolrock. Open pit quarrying of the dolomite is probably feasible at several places. Abandoned natural cement rock sub-surface mines may handicap quarrying locally.

GENERAL DESCRIPTION

The Shakopee dolomite is a formation of varying purity, some samples of which have been found to be a sub-woolrock requiring the addition of small amounts of shale, clay or sandstone to yield a mixture whose chemical composition lies within the composition limits of woolrock (p. 168). The formation crops out almost continuously in the north bluff of Illinois River for a distance of about 2 miles from Utica west to the center of the NE. ¼ sec. 13, T. 33 N., R. 1 E., near Split Rock, and is also exposed in the flat of Illinois valley in the quarries of the Utica Hydraulic Cement Company at Utica.

[39] Alden, W. C., Chicago Folio, U. S. Geol. Survey Geologic Atlas, Folio No. 81, 1902; Economic Geology sheet, Calumet Quad.
[40] Personal communication, George Otto, Illinois Geological Survey.

The lithologic character of the Shakopee formation is highly varied. It includes beds of fine grained dolomite, cherty dolomite, dolomitic sandstone, and chert, which in the main occur in layers mostly less than a foot thick. Its color is usually gray or buff. Much of it is dense, but porous beds are also present. The thickness of the Shakopee varies from 170 to 232 feet;[41] a well at Utica encountered 184 feet of the formation. The maximum thickness exposed is about 100 feet at the mouth of Pecumsaugan Creek.

Noteworthy among the varied beds of the formation are two beds of natural cement rock. About 2 miles west of Utica these beds are about 20 feet apart vertically; near Utica the interval between them is greater.[42] The upper bed is about 7 feet thick and the lower 8 to 20 feet thick. They were formerly extensively worked by subsurface mining in the bluffs west of Utica and the upper bed is being quarried at present by open pit and subsurface methods from the flat of Illinois River at Utica, for the manufacture of natural cement.

The formation lowers or dips gently towards the east, excepting near Split Rock where the dip is westward. Near the mouth of Pecumsaugan Creek one of the beds of "cement rock" is "about 20 to 25 feet above the railroad track. About a mile east the same bed is about 4 feet above the railroad track; and by reason of a monoclinal fold half a mile farther east, it is 20 feet below, bringing it beneath the valley floor in the vicinity of Utica."[43]

A number of samples of the Shakopee dolomite have been tested (Table 1, p. 64), and explanatory data regarding the source of the samples are given below. Samples *DX-18* and *DX-19* are sub-woolrocks. The other samples with the exception of *W-82* have CO_2 contents close to the upper CO_2 limits of sub-woolrocks and, like samples *DX-18* and *DX-19*, may be combined with shale or sandstone (p. 174).

Samples *DX-18* and *DX-19* were obtained from the following exposure in the north bluff of Illinois River near the west line of the SW. ¼ SW. ¼ sec. 8, T. 33 N., R. 2 E., about a mile west of Utica:

	Thickness *Feet*
4. Dolomite, cherty, porous, brown; sandy beds common	15
3. Dolomite, with beds of sandstone and chert	25
2. Dolomite, fine grained, gray, thin bedded	7
1. Dolomite, sandy; and dolomitic sandstone interbedded with layers of non-sandy dolomite 4 to 8 inches thick	19

Sample *DX-18* was taken from beds 1 and 2, totaling 26 feet in thickness; *DX-19* was obtained from beds 3 and 4, totaling 40 feet thick.

[41] Cady, G. H., Geology and mineral resources of the Hennepin and LaSalle quadrangles; Illinois State Geol. Survey Bull. 37, 1919, p. 35.
[42] Cady, Op. cit., p. 114.
[43] Cady, G. H., The structure of the LaSalle anticline; Illinois State Geol. Survey Bull. 36, 1920, p. 109.

Sample *W-82* was taken from a 66-foot exposure of Shakopee formation in the Illinois bluff in the center SE. ¼ SE. ¼ sec. 7, T. 33 N., R. 2 E.

Sample *DS-56* was taken from 11 feet of dolomite overlying the cement rock in the quarry of the Utica Hydraulic Cement Company at Utica in the center of the NE. ¼ sec. 17, T. 33 N., R. 2 E. The dolomite sampled included 5 feet of fine grained, gray dolomite and 6 feet of gray, porous, cherty dolomite.

Sample *DS-57* was obtained from the river bluff near the center of the SE. ¼ SW. ¼ sec. 8, T. 33 N., R. 2 E., from a 60-foot exposure.

Samples *C-14a* and *C-14b*[45] were taken respectively from the upper 6- to 8-foot bed of hydraulic cement rock and the lower 12- to 14-foot bed of cement rock in the mines near the SW. corner of sec. 8, T. 33 N., R. 2 E.

DEVELOPMENT CONSIDERATIONS

In the north bluff of Illinois River the Shakopee dolomite is generally overlain by sandstone of the St. Peter formation excepting for a comparatively narrow tract along the margin of the bluff and for an area of about 40 acres on the west side of Pecumsaugan Creek and north of the Chicago Rock Island and Pacific Railroad.[46] The unconsolidated overburden on this tract is probably thin in most places.

East of Pecumsaugan Creek in the angle between the creek and the railroad, exploration may reveal areas where the sandstone overlying the dolomite is thin. Unconsolidated overburden is also thought to be thin in this tract. Elsewhere in the bluff in the SE. ¼ sec. 7, and in sec. 8, T. 33 N., R. 2 E., a thin covering of St. Peter sandstone and sand and gravel overlies the Shakopee dolomite at some places.

In the uplands back from the bluff Shakopee dolomite occurs under thin overburden throughout most of the NE. ¼ sec. 12, T. 33 N., R. 1 E.[47] Almost the entire thickness of the formation is present. Railroad transportation is available at the foot of the bluffs about a mile south.

Secs. 17 and 18, T. 33 N., R. 2 E., in the flood plain of Illinois River are largely underlain by the Shakopee formation with no consolidated overburden. The stone is at or very close to the surface in a large part of sec. 17 and in the NW. ¼ sec. 18. Elsewhere it is generally buried by clay, silt, sand and gravel, in most places more than 20 feet thick.

Thorough prospecting and testing of samples are recommended to determine the most feasible sites for quarries. Such data will also afford a basis for evaluating the desirability of open pit operations exploiting 50 to 60 feet of rock, as against sub-surface mining of certain thicknesses of stone selected because of their physical or chemical character.

---

[45] Bleininger, A. V., Lines, E. F., and Layman, F. E., Portland Cement Resources of Illinois: Illinois State Geol. Survey Bull. 17, 1912, pp. 86 and 98.

[46] Cady, Op. cit., Plates I and II.

[47] Cady, Op. cit., Plates I and II.

Silica sand for mixing with the dolomite is available from the St. Peter formation either from quarries in the Illinois River bluff immediately east of Utica or from outcrops where the sandstone formation overlies the Shakopee formation in the bluffs. "Coal Measures" sandstone is obtainable from outcrops along both the Vermilion and Little Vermilion rivers near Oglesby and LaSalle. Pebbly clay is available from the overburden on the bedrock locally and from overburden on the St. Peter sandstone immediately east of Utica; shale is available from the bluffs west of Split Rock about 2½ miles west of Utica, from mine dumps in the vicinity of LaSalle and Spring Valley, and from shale deposits west of Ottawa. Both fireclay and shale may be obtained from deposits on the upland south of Utica.

The Chicago, Rock Island and Pacific Railroad traverses the base of the Illinois River bluff, and the Chicago and Illinois Valley Railroad is a few hundred feet south of the bluff. The Illinois Waterway is a mile to a mile and a quarter south of the bluff.

WORKABILITY OF DEPOSITS UNCERTAIN

Divine Area
(Grundy County)

RICHMOND SHALE NEAR DIVINE

SUMMARY

A sample of Richmond shale obtained from a waste heap at Dresden Island lock of Illinois Waterway is a sub-woolrock closely approaching a woolrock. The Richmond shale underlies a considerable area in the vicinity but the extent and character of the shale represented by the sample is unknown.

GENERAL DESCRIPTION

West and north of Divine, center N. ½ sec. 34, T. 34 N., R. 8 E., Grundy County, Richmond shale underlies the surficial materials of an area several hundred acres in extent.[48] This shale was encountered in excavations made for foundations at the Dresden Island locks and dam of the Illinois Waterway in sec. 26, T. 34 N., R. 8 E., and a sample *(DS-94)* taken from a waste heap was found to be a sub-woolrock, requiring the addition of limestone or dolomite (Table 1, p. 58; also p. 174). These materials are available from the Divine limestone and dolomite formation which overlies the shale over large areas in the vicinity of Divine.

The thickness of the Richmond shale in the Divine region varies from a few inches to 70 feet and probably exceeds 30 feet over large areas. The Divine limestone varies from a few inches to 44 feet in thickness and averages 15 to 25 feet throughout extensive tracts. The upper few feet of this limestone characteristically contain more than 95 per cent calcium carbonate but with depth the calcium carbonate content decreases and the magnesium carbonate content increases so that the basal beds of the formation are dolomite.

DEVELOPMENT CONSIDERATIONS

As (1) the position of the shale sampled with reference to the top of the Richmond formation, (2) the thickness of the material represented by the sample and (3) its lateral extent are unknown, thorough exploration by test drilling and testing of samples is necessary to evaluate the possibilities of the Richmond shale in the Divine area.

---

[48] For maps and detailed description of the geology of the Divine area see Illinois State Geol. Survey Report of Investigations 23 and Information Circular No. 4.

Milan Area
(Rock Island County)

SHALY LIMESTONE NEAR MILAN

SUMMARY

A sample of Devonian limestone taken from an outcrop along Mill Creek about 1¼ miles southeast of Milan has been found to be sub-woolrock. Exploration may reveal deposits of such size and character as to be of commercial importance.

GENERAL DESCRIPTION

Along the lower course of Mill Creek, in sec. 25, T. 17 N., R. 2 W., limestone of Middle Devonian age is exposed in the creek bed and in tributary gullies for more than ½ mile and also crops out along the same creek in the SW. ¼ sec. 30, T. 17 N., R. 1. W.[49] Two samples, *DS-68* and *69,* were taken from an outcrop in the SE. ¼ SE. ¼ NW. ¼ of sec. 25.

The exposure sampled consists of a 12-foot basal unit of gray, fine grained limestone in beds about 12 inches thick with a few shaly beds varying from 4 to 10 inches thick. Sample *DS-68,* taken from the basal 12-foot unit is a comparatively pure limestone. Above the basal beds are 14 feet of shaly limestone, poorly bedded but highly fractured, from which sample *DS-69* was taken. It was found to be a sub-woolrock requiring the addition of shale, clay, or sandstone (Table 1, p. 63; also p. 174).

Overburden consists of pebbly clay which varies from a few inches at the outcrop to about 15 feet in the adjoining tract west and south of the outcrop.

DEVELOPMENT CONSIDERATIONS

Detailed exploration may reveal in the vicinity comparatively extensive deposits of Devonian limestone similar to sample *DS-69* with an average of less than 20 feet of overburden. Locally the shaly limestone may reach a thickness of 25 feet. It is possible that in places the stone will be found to be sufficiently clayey that the addition of clay, shale, or sandstone will be unnecessary. However, clay is available from the overburden and shale or sandstone from outcrops of Pennsylvanian beds in the vicinity, especially along Mill Creek in sec. 31, and Case Creek in sec. 32, T. 17 N., R. 1 W.[50]

Overburden in the general area is unconsolidated clay and locally bedrock, shale, and sandstone. Its thickness is highly variable, ranging from a few feet at outcrops to a maximum of 50 or 60 feet.

The Peoria line of the Chicago, Rock Island and Pacific Railroad is about a mile north of the outcrop sampled.

---

[49] Savage, T. E., and Udden, J. A., Geology and Mineral Resources of the Edgington and Milan Quadrangles: Illinois State Geol. Survey Bull. 38, 1922, Plate II.
[50] Idem.

CHAPTER III—WOOLROCK AND SUB-WOOLROCK IN LESS ECONOMICALLY FAVORABLE AREAS

Woolrock Deposit

WORKABILITY UNCERTAIN

Cooperstown Area[1]
(Brown County)

SALEM FORMATION NEAR COOPERSTOWN

SUMMARY

A sample of interbedded limestone and shale obtained from the Salem formation near Cooperstown has been found to be woolrock. The deposit lacks transportation facilities and is consequently of uncertain economic importance. Exploration may reveal other deposits of Salem limestone better located with reference to transportation.

GENERAL DESCRIPTION AND DEVELOPMENT CONSIDERATIONS

Fifteeen feet of shale and limestone belonging to the Salem formation is exposed in the floor and lower walls of a small valley tributary to Lamoine River at the center of the east line SE. 1/4 NE. 1/4 SE. 1/4 sec. 15, T. 1 S., R. 2 W., about a mile north of Cooperstown. The exposure consists of four beds of calcareous, mostly sandy shale totaling about 3 feet in thickness, and eight beds of dolomitic limestone, mostly sandy, totaling about 12 feet in thickness. The overburden at the outcrop consists of 15 to 20 feet of comparatively pure St. Louis limestone and soil. Sample *R-142* from this outcrop of the Salem formation is a woolrock (Table 6, p. 118).

The deposit would probably have to be worked by subsurface mining because of the thickness of the overburden which increases to 40 feet or more a short distance from the outcrop. As the Salem formation is composed of a number of beds which are likely to vary laterally in composition and thickness, prospecting and testing before development should be thorough. The nearest railroad is about 6 miles airline southwest of the deposit. Illinois River is 4½ miles distant, but grain barges are known to have come up Lamoine River (Crooked Creek) to a point a mile and a quarter downstream.

The deposit itself is probably not of great commercial significance because of the lack of transportation. However, it is roughly typical of other similar small outcrops of the Salem formation, which occur in and near Illinois River bluff, usually beneath the St. Louis limestone and low in the bluffs, in eastern Brown and southern Schuyler counties. Exploration and prospecting will probably reveal other similar deposits closer to transportation.

[1] Deposit sampled and described by Mr. T. B. Root, Illinois Geol. Survey.

Deposits of Sub-Woolrock

DEPOSIT PROBABLY WORKABLE

Princeville Area
(Peoria County)

LONSDALE LIMESTONE NEAR PRINCEVILLE

SUMMARY

"Coal Measures" limestone, 10 to 12 feet thick, crops out in broad hills east and northeast of Princeville, Peoria County. Chemical analyses show the limestone to be sub-woolrock. The deposits from which analyses are available are about 1½ miles from a railroad; other broad hills near the railroads also contain limestone which may be of similar character.

GENERAL DESCRIPTION AND DEVELOPMENT CONSIDERATIONS

Deposits of limestone occur in broad upland hills about three miles northeast of Princeville and samples are shown by chemical analyses to be sub-woolrock. The addition of shale, clay or sandstone to the samples tested would yield a mixture whose chemical composition lies within the limits of woolrock. An outcrop reported in the SE. ¼ sec. 5, T. 11 N., R. 7 E., is described as follows:

Geologic section near Princeville[2]

	Thickness *Feet*
3. Soil	3
2. Limestone, fine grained, argillaceous and siliceous, in layers from ½ inch thick at top to 4 inches thick at bottom; in the more weathered portion much broken vertically into fragments or "chip rock"	12
1. Limestone, coarse grained, grayish, containing calcite crystals and fossils; exposed	1½

The total thickness of bed No. 1 is said to be 4 to 5 feet, and it is reported to be underlain by clay shale containing a thin coal. Sample *Bu-S* (Table 6, p. 118) was taken from the limestone exposed in the above section.

Another sample, *E-26* (Table 6), was taken from a 10-foot bed of thin bedded, white limestone exposed in a quarry on the west side of the road in the SE. ¼ sec. 5, T. 11 N., R. 7 E.[3]

---

[2] Bleininger, A. V., Lines, E. F., and Layman, F. E., Portland cement resources of Illinois, Illinois State Geol. Survey Bull. 17, p. 89, 1912.
[3] Bleininger, Lines, and Layman, Op. cit., p. 90.

These outcrops are probably typical of several others exposing 12 to 14 feet of limestone and occurring in secs. 4, 5, 6, 7, 19 and 20, T. 11 N., R. 7 E. It is stated[4] that "at each of the three places in sections 4 and 5 at least 20 acres of rock (limestone) from 10–12 feet thick underlies less than 10 feet of cover."

No analyses of the shale underlying the limestone are available but it will probably be of satisfactory chemical composition for mixing with the limestone. In places the shale is reported to contain a thin coal bed. The desirability of including this material with the rock wool mix should be determined by experiment.

The deposits described are about 1½ miles east of the Chicago Rock Island and Pacific Railroad. Another broad hill in the E. ½ of sec. 7 and the W. ½ of sec. 8, and hills in secs. 19 and 20, T. 11 N., R. 7 E., are within half a mile of railroads and prospecting may reveal similar limestone and shale in these hills.

Prospecting by drilling and thorough testing of samples are recommended before development is attempted.

---

[4] Bleininger, Lines and Layman, Op. cit., p. 89.

WORKABILITY OF DEPOSITS UNCERTAIN

Mill Creek Area
(Union County)

CALCAREOUS CHERT NEAR MILL CREEK

SUMMARY

A sample of calcareous chert obtained from a 6-foot exposure about a mile north of Mill Creek has been found to be a sub-woolrock. Thorough prospecting and testing are needed to evaluate the rock wool making possibilities of the deposits in the vicinity of Mill Creek.

GENERAL DESCRIPTION AND DEVELOPMENT CONSIDERATIONS

A sample, *NF-71,* obtained from an outcrop of calcareous chert, probably a part of the Springville formation,[5] in a hill along the road between Mill Creek and Jonesboro, near the center of sec. 30, T. 13 S., R. 1 W., has been found to be a sub-woolrock requiring the addition of limestone (Table 6, p. 118; also p. 174). The exposure is as follows:

Exposure near Mill Creek

	Thickness *Feet*
Clayey silt	0–25±
Chert, porous, rotted; brown, yellow and red; noncalcareous	8–10
Chert, gray, thin bedded, calcareous, yellow along joints. (Sample *NF-71*)	6+
Covered	

The chert crops out locally throughout most of the area along the Mobile and Ohio Railroad from Springville to Elco, and in adjoining regions. The extent and total thickness of the calcareous portion of the chert is not accurately known. At the outcrop sampled the carbonate content may increase with depth. Drilling and chemical analyses of samples thus obtained are required to determine these data.

The Salem-Warsaw formation, which is widespread throughout most of the area, is a convenient source of limestone for mixing with the chert to give the required chemical composition for a rock wool raw mix. In general the formation contains over 90 per cent carbonates although in places it is less pure and cherty. The Salem-Warsaw formation probably comprises the higher parts of the hills in the Mill Creek-Springville region and outcrops at a number of places north of Springville, as along the Mobile and Ohio Railroad near the SW. corner sec. 7, T. 13 S., R. 1 W., at a number of places in the SE. 1/4 sec. 1, T. 13 S., R. 2 W., and at several places in the hill bordering the railroad about 1/2 mile north of Springville.

Exploration by test drilling will doubtless reveal other deposits of calcareous chert in the general Springville-Mill Creek region similar to the one

[5] Savage, T. E., Geology and Mineral Resources of the Jonesboro Quadrangle: Illinois State Geol. Survey, Unpublished manuscript.

described. Where overlying limestone beds are not present most deposits will probably have an overburden of weathered noncalcareous chert. An unconsolidated overburden of clayey silt is present which reaches a maximum thickness of about 25 feet on the tops of the hills and ridges. It is thought likely, however, that the lower hill slopes may generally have an unconsolidated overburden averaging 15 to 20 feet or less.

The Mobile and Ohio Railroad traverses the area.

Peoria-Farmington Area

(Peoria County)

LONSDALE LIMESTONE BETWEEN PEORIA AND FARMINGTON

SUMMARY

The Lonsdale limestone, a "Coal Measures" limestone ranging in thickness up to 21 feet, crops out in the heads of many valleys intersecting an elongate upland tract extending east-west between Peoria and Farmington and probably underlies much of the upland. Samples of the limestone have been found to be sub-woolrock. Overburden is variable in character and thickness; exploration may reveal sizable tracts with an overburden averaging less than 15 feet.

INTRODUCTION

Samples of the Lonsdale limestone of "Coal Measures" age from the Peoria-Farmington area have been found to be sub-woolrock. This limestone underlies an upland tract between Peoria and Farmington which is followed roughly by the Minneapolis and St. Louis Railroad from Farmington east to a point about 2 miles east of Hanna City; east of this point the railroad traverses the south side of the tract. That part of the upland tract underlain by Lonsdale limestone terminates at about the center of the south line sec. 2, T. 8 N., R. 7 E.

DISTRIBUTION

Most of the outcrops of the Lonsdale limestone occur along or in the upper parts of valleys and appear most commonly on both sides of the upland at elevations between 650 and 700 feet above sea level, excepting north of Cramer and Trivoli where the limestone exposures are commonly above 700 feet. Outcrops are present in many of the valleys but some valleys show no limestone, though older formations are exposed. This may be due to the fact that the limestone is obscured by overlying glacial clay deposits, or may have been worn away previous to the deposition of the clay. Nixon Creek in the SW. part of T. 9 N., R. 6 E., is such a valley, as is also Tiber Creek in secs. 27 and 34, T. 8 N., R. 5 E., and the upper portion of an unnamed creek about one mile west of Smithville in sec. 27, T. 8 N., R. 6 E., and upstream from this section.

CHARACTER OF LONSDALE LIMESTONE

The lithologic character of the Lonsdale limestone is typically variable. An impure nodular or brecciated stratum characterizes the upper part of the formation in many places and is underlain by a well bedded, gray or dark gray limestone of comparatively high carbonate content. Elsewhere the formation may be largely impure, in some places brecciated, in others well bedded, or the formation may be largely comparatively pure limestone.

In the SW. ¼ NW. ¼ SW. ¼ sec. 3, T. 8 N., R. 7 E., the following section is exposed and shows the two-fold division of the Lonsdale characteristic in some places.

Exposure in sec. 3, T. 8 N., R. 7 E.

			Thickness *Feet*
4.	Pebbly clay		0–15+
3.	Limestone, nodular, fine grained, gray	Lonsdale limestone	9
2.	Limestone, fine grained, bluish-gray, in beds 6-9 inches thick		6
1.	Shale, black, laminated		10+

Sample *DS-54* is from the shale of bed 1, and *DS-55* from the limestone of beds 2 and 3.

Another section exposed in an old quarry in the SE. ¼ sec. 10, T. 8 N., R. 7 E., follows:[6]

Exposure in sec. 10, T. 8 N., R. 7 E.

		Thickness *Feet*
7.	Soil, sandy	1 to 2
6.	Limestone, loose, white, nodular. (Sample *E-24a*)	3 to 4
5.	Limestone, gray, containing fossils. (Sample *E-24b*)	6 to 7
4.	Same as No. 5, but evenly bedded. (Sample *E-24c*)	3
3.	Shale, gray	½
2.	Shale, black, slaty, bituminous, nearly coal at some exposures	5
1.	Shale, gray	20

Another sample *Bu-9* is composite of 13½ feet of limestone exposed in the same quarry.[7]

The results of analyses of the samples of limestone and shale mentioned above are given in Table 6 (p. 118), and show that all the samples excepting *DS-54* (shale) and *E-24c* (limestone) are sub-woolrocks (p. 174).

Thickness.—The thickness of the Lonsdale limestone varies locally from a foot to 21 feet but the normal average thickness when the bed is well developed is probably about 12 to 15 feet. Twenty-one feet of the limestone is

[6] Bleininger, A. V., Lines, E. F., and Layman, F. E., Portland cement resources of Illinois: Illinois State Geol. Survey Bull. 17, 1912, p. 90. The location given is probably more exactly SE. ¼ NE. ¼ sec. 10.

[7] Bleininger, Lines, and Layman, Op. cit., p. 89.

reported in a ravine running east-west through the N. ½ sec. 6, T. 8 N., R. 7 E.,[8] and a similar thickness occurs in a northeast-southwest trending ravine in the W. ½ SW. ¼ sec. 35, T. 9 N., R. 5 E. [9]

SOURCES OF SHALE, CLAY, OR SANDSTONE

As the samples of the Lonsdale limestone are sub-woolrocks, the addition of shale, clay, or sandstone to the limestone is necessary to yield a mixture whose chemical composition lies within the composition limits of woolrock (p. 168). There are two sources of argillaceous material associated with the limestone, the glacial, pebbly clay which overlies the limestone at many places, and the "Coal Measures" shale which underlies it at some places. In view of the fact that the chemical composition of the clay probably varies more than that of the shale, the shale will be the more suitable material for mixing with the limestone for making rock wool. Usually the shale below the Lonsdale limestone is dark gray or black. At the outcrop mentioned above from which sample *DS-54* (Table 6, p. 118) was obtained, the shale was non-gritty and uniform in texture.

Sandstone, some of it massive, occurs locally immediately below the limestone and in some places immediately above it.

OVERBURDEN

Throughout a considerable portion of the upland tract, the Lonsdale limestone is probably overlain only by pebbly clay and clayey silt of glacial origin. The thickness of this clay and silt ranges from a few feet at the limestone outcrops to 50 feet or more in the higher parts of the uplands. In the vicinity of Cramer and Trivoli the limestone is overlain by a sandstone bed and locally other "Coal Measures" strata which are in turn overlain by glacial clay. A similar condition exists in the vicinity of Hanna City and probably elsewhere.

DEVELOPEMENT CONSIDERATIONS

Because of the proximity of railroad transportation, the region north of Cramer and northeast of Trivoli, and the region north and east of Hanna City offer most promise of development. Data which make possible the selection of specific favorable sites are not at hand but it seems likely that an intensive study of outcrops in these tracts and probably elsewhere, supplemented by test drilling, may reveal sizable tracts beneath parts of the upland and along the walls of valleys, underlain by Lonsdale limestone with an overburden averaging less than 15 feet thick. The variable nature of the limestone makes thorough testing desirable.

---

[8] Udden, J. A., Geology and Mineral Resources of the Peoria quadrangle: U. S. Geol. Survey Bull. 506, p. 38, 1912.

[9] Bevan, A. C., Illinois State Geol. Survey, Unpublished notes of the Glasford quadrangle.

Table 6—*Chemical analyses of bedrock materials in less economically favorable areas*

Area	Sample No.	Formation	Material	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	MgO	CaO	CO_2	H_2O-	Loss on ignition 110-400°C.	Loss on ignition 400-1000°C.	Loss on ignition	Other constituents
Cooperstown P. 111	R-142 (*a*)	Salem.........	Woolrock......	30.78	2.15	2.60	....	7.29	26.12	30.00	0.0	......	......	30.88	TiO_2–0.0, Na_2O–0.31, K_2O–0.50, S–0.06
Millcreek P. 114	NF-71 (*a*)	Springville	Sub-woolrock..	57.0	1.39	3.01	....	2.1	21.1	.....	0.0	0.1	17.3	......	
Peoria-Farmington P. 115	Bu-9 (*b*)	Lonsdale......	Sub-woolrock..	14.24	....	....	3.98	0.46	45.30	.....	0.23	......	......	36.70	
	DS-54 (*a*)	"Coal Measures"...	Shale.........	.....	....	....	....	....	.....	.....	....	......	4.4	......	
	DS-55 (*a*)	Lonsdale......	Sub-woolrock..	15.27	2.26	1.04	....	0.78	45.15	.....	0.42	0.04	35.40	35.86	
	E-24a (*b*)	Lonsdale......	Sub-woolrock..	21.96	....	....	5.88	0.48	39.26	.....	0.48	......	......	32.88	
	E-24b (*b*)	Lonsdale......	Sub-woolrock..	21.04	....	....	3.70	0.56	41.38	.....	0.25	......	......	33.70	
	E-24c (*b*)	Lonsdale......	Limestone.....	2.78	....	....	1.82	1.86	51.52	.....	0.12	......	......	42.70	
Princeville P. 112	Bu-8 (*b*)	Lonsdale......	Sub-woolrock..	13.36	....	....	3.24	0.42	46.74	.....	0.14	......	......	37.94	
	E-26 (*b*)	Lonsdale......	Sub-woolrock..	16.46	....	....	3.30	0.50	44.18	.....	0.26	......	......	35.92	

(*a*) Analyses made in the Analytical Division of the State Geological Survey by C. S. Westerberg and L. D. McVickers under the direction of Dr. O. W. Rees.

(*b*) Illinois State Geol. Survey Bull. 17, 1912, p. 99.

CHAPTER IV—UNCONSOLIDATED MATERIALS

Unconsolidated materials of Pleistocene age, such as gravel, sand, or clay, are the only rocks exposed at the surface over much of Illinois. Some of these materials are of such chemical composition as to fall within the range of woolrocks but because of their physical character it is questionable whether they could be used commercially in the present equipment employed for rock wool manufacture. The engineering problems involved in the use of these materials can doubtless be worked out and processes developed for using unconsolidated rocks for rock wool manufacture. These problems and the economics involved are beyond the scope of the present investigation. For those interested in such matters, however, data are given regarding the chemical composition of a number of unconsolidated rock materials of Illinois together with a brief description of the deposits from which the samples were obtained.

SAND AND GRAVEL

Summary

Samples were obtained from 14 typical sand and gravel deposits in the northern part of Illinois and were screened to 4 sizes. Based on CO_2 content (p. 122), the minus 4-mesh portion of all samples is of such chemical composition as to fall within or very close to the composition limits of woolrock. Coarser materials of some samples are also woolrocks or sub-woolrocks on the basis of similar data.

General Description

Samples obtained by channeling were secured from 14 typical sand and gravel deposits in northern Illinois, many of them in regions devoid of bedrock exposures. Because of the well known variability of gravel deposits these samples, although thought to be representative of the deposits at the places sampled, are not necessarily representative of the deposits as a whole. Detailed and extensive sampling is necessary to secure such information. These samples, however, are thought to give a general picture of the nature of Illinois gravels. In all cases boulders over 6 inches in diameter were excluded. A brief description of the deposits sampled arranged by sample numbers follows:

Sample DX-2.—Wisconsin Lime and Cement Co., Crystal Lake, McHenry County, NW. ¼ NW. ¼ NE. ¼ sec. 11, T. 43 N., R. 8 E.

Sample from 20 feet of poorly sorted cobbly gravel comprising the upper part of a 50-foot face about 1/4 mile northeast of loading bins. The lower 30 feet were slumped and could not be sampled.

Sample DX-6.—Paul Ales, Inc., Lockport, Will County, NW. 1/4 NE. 1/4 NW. 1/4 sec. 22, T. 36 N., R. 10 E.

Sample from 16 feet of cobbly gravel comprising the upper part of a 31-foot face. Lower 15 feet not available.

Sample DX-7.—Gravel pit at west end of east part of Channahon Mound, Will County, NE. 1/4 NE. 1/4 NW. 1/4 sec. 16, T. 34 N., R. 9 E.

Sample from 10 feet of gravel; upper 3 feet fine gravel, lower 7 feet sandy gravel.

Sample DX-8.—Gravel pit along east side of DuPage River, 1 1/4 mile northwest of Channahon, Will County, NW. 1/4 NE. 1/4 NE. 1/4 sec. 7, T. 34 N., R. 9 E.

Sample from lower 6 feet of an 8-foot exposure of coarse gravel.

Samples DX-9 and 10.—Gravel pit in mound two miles northeast of Blodgett, Will County, SE. 1/4 NW. 1/4 SE. 1/4 sec. 35, T. 34 N., R. 9 E.

Sample *DX-9* from upper 20 feet of sandy gravel; Sample *DX-10* from lower 10 feet of sandy gravel with several silt bands 8 to 10 inches thick and several sand lenses.

Sample DX-11.—Small gravel pit along concrete road 2 miles east of Ottawa, LaSalle County, SW. 1/4 NW. 1/4 NW. 1/4 sec. 9, T. 33 N., R. 4 E.

Sample from 12 feet of gravel in terrace along south wall of Illinois valley.

Sample DX-12.—Pit of Lehigh Stone Company at Moronts, Putnam County, NW. 1/4 SW. 1/4 NW. 1/4 sec. 30, T. 33 N., R. 1 W.

Sample from 25 feet of gravel.

Sample DX-16.—Pit of Western Sand and Gravel Company at Spring Valley, Bureau County, SW. 1/4 NE. 1/4 SE. 1/4 sec. 35, T. 16 N., R. 11 E.

Grab sample from several parts of the pit.

Samples NF-9 and 10.—Gravel pit along State Route 19 east of Fox River Grove, McHenry County, SE. 1/4 NE. 1/4 NW. 1/4 sec. 20, T. 43 N., R. 9 E.

Sample *NF-9* from 18 feet of coarse gravel in westernmost pit; *NF-10* from 6 feet of fine gravel in easternmost pit.

Sample NF-26.—Pit of Chas. E. Giertz & Son, Elgin, Cook County, NE. 1/4 NE. 1/4 NW. 1/4 sec. 29, T. 41 N., R. 9 E.

Sample from upper 20 feet of deposit.

Sample NF-34.—Morton Gravel Company, Munger, DuPage County, NW. 1/4 SW. 1/4 NW. 1/4 sec. 8, T. 40 N., R. 9 E.

Sample from 8 1/2 feet of gravel in small pit. Large pit water filled.

Sample NF-35.—Morton Gravel Company, South Elgin, Kane County, NW. 1/4 SE. 1/4 SW. 1/4 sec. 2, T. 40 N., R. 8 E.

Sample from 23 feet of gravel in large pit.

Sample NF-45.—South Elgin Gravel Company, South Elgin, Kane County, SE. ¼ SE. ¼ sec. 35, T. 41 N., R. 8 E.

Sample from 12 feet of gravel reported to be typical of deposit.

Sample NF-51.—Chicago Gravel Company, Plainfield, Will County, SW. ¼ NW. ¼ NE. ¼ sec. 15, T. 36 N., R. 9 E.

Sample from 9 feet of gravel in northeasternmost pit.

Sample NF-52.—Chicago Gravel Company, Plainfield, Will County, SE. ¼ SE. ¼ NW. ¼ sec. 15, T. 36 N., R. 9 E.

Sample from 9 feet of gravel in southwesternmost pit.

Each of the foregoing samples was screened to four sizes or grades as follows:

Grade A—Retained on a 1-inch screen.

Grade B—Passing a 1-inch screen, retained on a 4-mesh screen.

Grade C—Passing a 4-mesh screen, retained on a 20-mesh sieve.

Grade D—Passing a 20-mesh sieve.

Results of screen tests and CO_2 determinations on Grades B, C, and D are given in Table 7. Laboratory tests indicates that Grade A is generally too high in limestone and dolomite to be of proper composition for rock wool manufacture. The CO_2 content of grades C and D combined, in every case lies within or very close to the CO_2 range of woolrock. The combined B, C, and D grades of some samples also have CO_2 contents within the requisite range.

In order to determine in greater detail the chemical composition of the minus 4-mesh material of a typical gravel, grades C (passing 4-mesh, retained on 20-mesh) and D (passing 20-mesh) of sample *NF-35,* which approximates the average figures given in Table 7, was made with the following results:

Analysis of Grades C and D of sample NF-35

SiO_2	39.42	CaO	17.48
Al_2O_3	6.53	H_2O	0.26
Fe_2O_3	1.40	Loss on ignition	23.68
MgO	11.16		
		Total	99.67

It is to be noted that grades C and D, usually termed sand, constitute on the average 31 per cent of the samples studied, and that at some gravel plants the amount of sand necessarily handled in connection with the production of the requisite amount of gravel is in excess of the market for sand. If processes and apparatus can be developed for the profitable utilization of this material for rock wool manufacture, the surplus sand from some gravel operations may have a commercial outlet.

TABLE 7—*Tests on gravel samples*

Sample No.	Source	County	Screen tests—Per cent				CO_2* content (a)			CO_2 (b) content of combined grades B, C, and D—Per cent	Per cent of total sample in combined grades B, C, D	CO_2 (b) content of combined grades C and D—Per cent	Per cent of total sample in combined grades C and D
			Retained on 1″ screen	Passing 1″, retained on 4-mesh screen	Passing 4-mesh, retained on 20-mesh sieve	Passing 20-mesh sieve	Grade B—Per cent	Grade C—Per cent	Grade D—Per cent				
			Grade A	Grade B	Grade C	Grade D							
DX-2	Wisconsin Lime & Cement Co., Crystal Lake	McHenry	52.0	26.8	10.8	10.4	36.7	27.9	14.3	29.9	48.0	21.2	21.2
DX-6	Paul Ales, Inc., Lockport	Will	73.7	16.5	6.1	3.7	41.2	35.7	21.7	37.2	26.3	30.4	9.8
DX-7	Gravel mound near Channahon	Will	24.1	41.7	15.3	18.9	39.3	32.1	29.4	35.4	75.9	30.6	34.2
DX-8	Terrace north of Channahon	Will	45.3	37.5	9.9	7.3	38.6	26.5	24.0	34.5	54.7	25.4	17.2
DX-9	Mound N E. of Blodgett—upper part	Will	16.4	43.8	18.2	21.6	39.0	30.9	27.0	34.1	83.6	28.8	39.8
DX-10	Mound N. E. of Blodgett—lower part	Will	2.6	24.7	33.6	39.1	33.1	23.6	18.4	23.9	97.4	20.8	72.7
DX-11	Terrace east of Ottawa	LaSalle	40.4	25.4	20.1	14.1	33.1	28.4	17.5	27.8	59.6	23.9	34.2
DX-12	Lehigh Stone Co., Moronts	Putnam	20.8	39.9	29.3	10.0	29.0	24.4	11.1	25.0	79.2	21.0	39.3
DX-16	Western Sand & Gravel Co., Spring Valley	Bureau	40.6	37.0	15.0	7.4	35.2	25.3	9.6	29.5	59.4	20.1	22.4
NF-9	Near Fox River Grove	McHenry	57.5	23.4	11.2	7.9	37.1	31.4	18.9	32.2	42.5	26.2	19.1

NF-10	Near Fox River Grove	McHenry	29.6	35.7	26.4	8.3	36.3	33.4	19.9	33.3	70.4	30.2	34.7
NF-26	Chas. E. Giertz & Sons, Elgin	Cook	42.4	32.7	15.3	9.6	38.6	35.9	21.0	34.9	57.6	30.2	24.9
NF-34	Morton Gravel Co., Munger	DuPage	35.5	27.5	18.1	18.9	39.5	34.7	23.4	33.4	64.5	28.9	37.0
NF-35	Morton Gravel Co., S. Elgin	Kane	35.1	33.6	18.7	12.6	35.5	27.1	18.2	29.7	64.9	23.5	31.3
NF-45	South Elgin Gravel Co., S. Elgin	Kane	25.0	35.1	25.7	14.2	34.7	27.6	15.8	28.7	75.0	23.4	39.9
NF-51	Chicago Gravel Co., Plainfield	Will	42.3	32.8	15.3	9.6	39.6	31.5	30.8	36.0	57.7	31.2	24.9
NF-52	Chicago Gravel Co., Plainfield	Will	41.8	28.7	13.9	15.6	39.4	31.5	28.5	34.6	58.2	29.9	29.5
	Average		37	32	18	13	37	30	21	32	63	26	31

(a) Loss on ignition 400° to 1000°C. Chemical analyses made in Analytical Division of the State Geological Survey by C. S. Westerberg under the direction of Dr. O. W. Rees.

(b) Calculated.

CLAYS AND SILTS

Glacial Till

SUMMARY

Determinations on 37 till samples show that in general their CO_2 content is too low to fall within the range of woolrocks. However, some samples did fall within the woolrock limits and a number within the sub-woolrock limits. Large amounts of till are available in most parts of Illinois.

GENERAL DISCUSSION

Till is a pebbly clay of glacial origin which occurs in immense amounts in all parts of the State, excepting extreme southern Illinois and most of JoDaviess County and Calhoun County. Where unweathered, the till is calcareous but weathering has leached the carbonates from the upper part of many till deposits to a depth of 5 to 10 feet. The data at hand regarding the carbonate content, as measured by CO_2 determinations, of unleached Illinois tills suggest that in general the till is too low in carbonates to be a woolrock, although the CO_2 content of some samples falls within the requisite range for woolrocks, and that of a number within the sub-woolrock limits (p. 16). Table 8 gives data regarding the till samples studied. All samples were unleached or only partly leached excepting *DS-30* and *NF-88* which are leached.

Many of the till samples shown in Table 8 occur in areas where limestone or dolomite is abundant. The carbonate content of those tills which are too low in this constituent to fall within the woolrock class may be raised by the addition of some of these rocks.

The practicability of using till for rock wool manufacture is not known. If it is not possible to use till in the equipment now commonly employed for making rock wool it may be feasible to develop suitable equipment or to modify the till in such a way that it can be used in existing equipment, as, for example, forming it into blocks to be used with or without preliminary heating.

LOESS

Loess is a clayey silt, buff or gray in color, which occurs in large amounts in those parts of the State bordering the Mississippi, Ohio, and Illinois rivers. In many parts of the State the unweathered loess is calcareous; in extreme southern Illinois, most of the loess is noncalcareous. Three samples (Table 8) were tested but the carbonate content was found to be less than the minimum amount acceptable for woolrock. Remarks pertaining to the addition of limestone or dolomite to till for the purpose of obtaining a mixture of suitable composition for rock wool manufacture also apply to loess.

Miscellaneous

A sample of glacial silt (*NF-11*) evidently of lacustrine origin and a sample of alluvial silt (*DS-16*) both proved too low in CO_2 content to be a woolrock or sub-woolrock (Table 8). Both occur in areas where glacial till is available in immense amounts and they are, therefore, not thought to be of importance.

TABLE 8—*Results of CO_2 determinations on glacial clays and silts (a)*

County	Sample No.	Location						Near	Thickness sampled (feet)	CO_2 (*b*)	Kind of material
		T.	R.	Sec.	¼	¼	¼				
Alexander	DS-4	15S	3W	4	NW	SE	NW	Gale	48	5.52 (*c*)	Loess
Cook	DS-82	37N	14E	30	W½	SE	NE	Blue Island	....	9.51 (*c*)	Till (Tinley?)
Cook	DS-83	37N	14E	30	W½	SE	NE	Blue Island	9	11.0	Till (Tinley?)
Cook	DS-84	37N	14E	30	W½	SE	NE	Blue Island	19	12.8	Till (Tinley?)
Cook	DX-3	37N	11E	30	SE	SW	NW	Lemont	40	35.4	Till (Lemont)
Cook	NF-13	42N	9E	16	SW	NE	SE	Barrington	11	18.41	Till (Cary)
Cook	NF-14	42N	10E	8	SW	SE	NW	Barrington	5	2.28	Gravelly clay, probably till (Barrington)
Cook	NF-15	42N	10E	8	SW	SE	NW	Barrington	4	10.58	Till (Barrington)
Cook	NF-16	42N	10E	8	SW	SE	NW	Barrington	4	9.88	Till (Barrington)
Cook	NF-17	42N	10E	8	SW	SE	NW	Barrington	10	13.52	Till (Barrington)
Cook	NF-18	42N	9E	1	......	N½	SW	Barrington	9	16.23	Till (Barrington)
Cook	NF-21	41N	13E	25	......	N½	NW	Evanston	2½	12.82	Lacustrine clay (Lake Chicago)
Cook	NF-22	41N	13E	25	......	N½	NW	Evanston	2½	18.24	Till (Lake Border)
Cook	NF-23	41N	13E	25	......	N½	NW	Evanston	18	15.74	Till (Lake Border)
Cook	NF-24	41N	13E	25	......	N½	NW	Evanston	17	16.31	Till (Lake Border)
Cook	NF-63	39N	13E	33	SE	SW	SE	Cicero	20	11.99	Till (Tinley?)
Cook	NF-64	37N	12E	2	SW	SE	SE	Palos Park	11	11.16	Till (Tinley)
Cook	NF-66	37N	12E	4	SW	SW	SW	Willow Springs	11	11.18	Till (Valparaiso)
DuPage	NF-25	40N	9E	4	W½	NE	SE	Munger	8½	19.23	Till (West Chicago)
DuPage	NF-27	39N	9E	10	NE	NE	SW	West Chicago	8	21.21	Till (West Chicago)
Ford	DS-101	23N	10E	17	NW	NW	NW	Paxton	23	9.54 (*c*)	Till (Cropsey)
Grundy	DS-91	33N	6E	30	SE	NW	SE	Seneca	5	12.69 (*c*)	Till (Marseilles)
Jackson	DS-16	9S	1W	13	SW	NW	NW	Carbondale	4	2.48	Valley fill clay

Jackson	NF-74	9S	1W	33	NE	NE	NW	Carbondale	12	7.29	Till (Illinoian)
Kane	NF-32	40N	8E	3	......	S½	NW	Elgin	4	20.03	Till (Minooka)
Kane	NF-36	40N	8E	29	SW	SW	SE	St. Charles	5½	18.31	Till (Marseilles)
Kane	NF-49	40N	8E	15	SW	NE	SE	St. Charles	17	16.38	Till (Bloomington)
Lake	NF-1	44N	12E	4	N½	N½	NE	Waukegan	11	16.64	Till (Inner Lake Border)
Lake	NF-2	44N	12E	4	N½	N½	NE	Waukegan	38	16.99	Till (Inner Lake Border)
Lake	NF-3	44N	12E	20	SE	NW	NE	Lake Bluff	9	16.43	Till (Inner Lake Border)
Lake	NF-4	44N	12E	20	SE	NW	NE	Lake Bluff	10	16.63	Till (Inner Lake Border)
Lake	NF-5	44N	11E	22	SE	NW	NE	Roundout	11½	17.11	Till (Outer Lake Border)
Lake	NF-8	43N	11E	8	SW	NE	NE	Leithton	5	17.46	Till (Tinley Park?)
Lake	NF-11	43N	9E	28	NW	SE	NE	Barrington	9½	9.66	Silty Clay
Lake	NF-12	43N	9E	28	NW	SE	NE	Barrington	9½	25.81	Till (Cary?)
Lee	DS-71d	22N	9E	27	SE	SE	NW	Dixon	30	13.98 (c)	Till (Illinoian)
McHenry	DX-1	43N	8E	2	......	SW	SW	Crystal Lake	15	22.41	Till (West Chicago)
Madison	NF-87	5N	9W	17	SW	SW	NE	Alton	25	5.09	Loess
Marion	DS-30	1N	4E	25	NW	SE	SW	Helm	20	1.81	Till (Leached Illinoian)
St. Clair	NF-81	2N	9W	25	NE	NW	NW	French Village	25	11.52	Loess
St. Clair	NF-88	1N	9W	13	......	N½	N½	Belleville	4	1.67	Till (Leached Illinoian)
Will	DS-86	34N	13E	21	NW	SW	SW	Monee	28	11.2	Till (Valparaiso)

(a) Analyses made in Analytical Division of State Geological Survey by C. S. Westerberg under the direction of Dr. O. W. Rees.
(b) CO_2 approximated by loss on ignition 400-1000°C.
(c) Analytically determined CO_2.

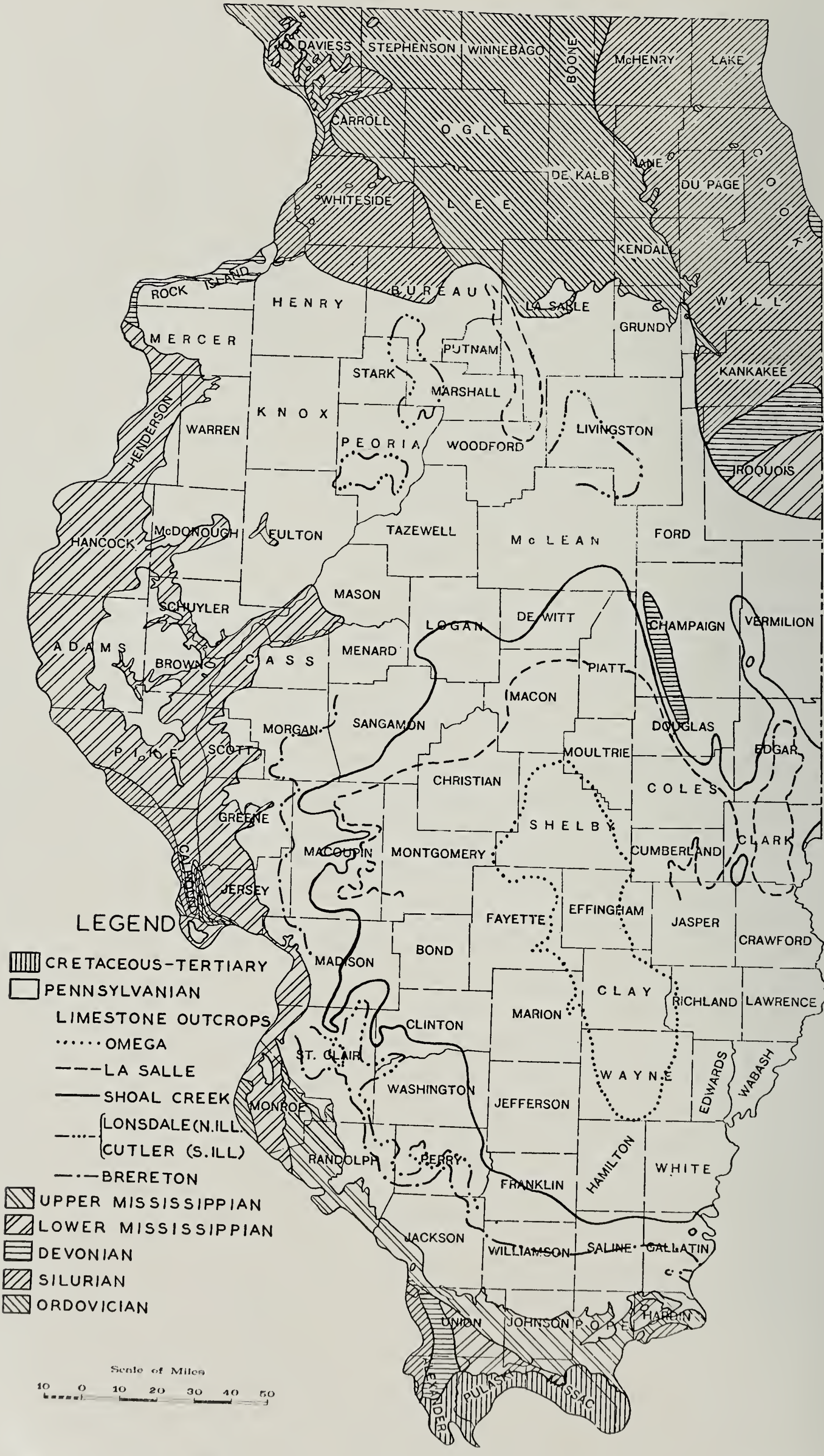


FIG. 14. Areal geologic map showing the distribution of the various bedrock systems and the Cretaceous-Tertiary systems as they would appear if the surficial materials covering them were removed. The small circular area above the "H" in Hardin County is Devonian. Outcrop lines of Pennsylvanian limestones are from unpublished maps by J. M. Weller and H. R. Wanless, State Geological Survey.

CHAPTER V—GENERAL GEOLOGY OF ILLINOIS RELATING TO ROCK WOOL MAKING MATERIALS

SUMMARY

The bedrock of Illinois consists principally of limestone, dolomite, sandstone, shale, and chert, and belongs to five major geologic systems (Fig. 14). The oldest system, the Ordovician, embraces two formations of potential interest for the manufacture of rock wool, the Shakopee which in places contains sub-woolrock, and the Maquoketa, which contains sub-woolrock or woolrock locally. The overlying system, the Silurian, includes an impure dolomite or highly cherty dolomite formation which is locally a sub-woolrock or woolrock. The Devonian system includes the cherty Bailey limestone in southern Illinois which is a woolrock over large areas, another impure limestone in Rock Island County, which is locally a sub-woolrock, and thick chert formations which may be sub-woolrocks in places in southern Illinois. The Mississippian system is largely devoid of woolrock or sub-woolrock though locally interbedded limestone and shale or cherty limestone may meet chemical requirements. The youngest or Pennsylvanian system is chiefly sandstone and shale but locally contains limestone strata which are woolrocks or sub-woolrocks.

The unconsolidated deposits which cover the bedrock over most of the State are Cretaceous-Tertiary and Pleistocene in age and consist of clay, silt, sand, and gravel. The potential use of the Pleistocene deposits as a source of rock wool materials is discussed in Chapter IV.

INTRODUCTION

It has been shown that in general the exposed consolidated woolrocks and sub-woolrocks consist principally of impure limestone or dolomite, highly cherty limestone or dolomite, calcareous or dolomitic shale, or interbedded shale and limestone or dolomite. In the subsequent discussion special emphasis is given to those geological formations composed wholly or partly of such materials or of materials of similar nature. However, mention is made of the general character of the other formations of the State to provide information which will assist in evaluating the possibilities of making rock wool from mixtures of various types of rocks.

CHEMICAL ANALYSES

Two tables giving chemical data regarding bedrock materials are presented at the end of this chapter. Table 12 gives typical analyses, largely detailed, of the various limestones, dolomites, shales, and bedrock clays. The analyses are arranged by geologic systems, formations, and by counties. It includes analyses published in other Survey reports,[1] unpublished data from the Survey files, and analyses made in connection with the rock wool investigations, including some analyses which have been given in another table but are repeated to make the present table as complete as possible.

Table 11 gives the results of CO_2 determinations not already cited on samples of bedrock taken during the present investigation. The data are arranged by counties.

GENERAL GEOLOGY OF ILLINOIS

The exposed bedrock materials of Illinois belong to five major groups or systems,[2] namely the Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian systems. The generalized areal distribution of each of these systems is shown in figure 14, which serves as an index to the rocks occurring in any given region. Each system is further subdivided into a number of series or formations. Below, the salient information regarding the various major series or formations of each system is briefly discussed.

Ordovician System

The Ordovician system is exposed extensively in the northern part of the State and to a limited extent in southern Illinois. It is comprised of the following formations:

Northern Illinois		*Southern Illinois*
	Upper Ordovician	
Maquoketa-Richmond		Maquoketa-Richmond
	Middle Ordovician	
Galena dolomite		Kimmswick limestone
Platteville limestone		Plattin limestone
Glenwood shale		Joachim limestone
St. Peter sandstone		St. Peter sandstone
	Lower Ordovician	
Shakopee dolomite		Cotter dolomite
New Richmond sandstone		

[1] Chiefly Illinois State Geol. Survey Bulls. 4, 9, 17 and 46.
[2] A small area underlain by Cambian rocks occurs near Oregon, Ill., but is inconsequential as a source of woolrock or sub-woolrock.

NEW RICHMOND SANDSTONE

This sandstone is known to outcrop only in a limited tract about one mile west of Franklin Grove, in Lee County. The sandstone is composed of silica sand and is loosely cemented.

SHAKOPEE DOLOMITE

The Shakopee dolomite is exposed in northern Illinois in the vicinity of Oregon in Ogle County, Franklin Grove in Lee County, and between Utica and LaSalle in LaSalle County. A small, relatively unimportant outcrop, tentatively correlated with the Cotter dolomite in Missouri, occurs along Mississippi River near Dogtown Landing in southern Calhoun County. The Shakopee formation is a dolomite which varies considerably in composition. Locally it contains sandy or cherty beds, and at Utica it includes beds of impure rock used for making natural cement. Some of the cherty or sandy parts of the formation are locally sub-woolrock.

ST. PETER SANDSTONE

The St. Peter sandstone crops out extensively in parts of LaSalle, Lee, and Ogle counties. Minor exposures occur in southern Calhoun and northern Winnebago counties. The formation is composed of loosely cemented silica sand.

GLENWOOD FORMATION

The Glenwood formation crops out in Lee and Ogle counties in the northern part of the State. It is a comparatively thin formation composed in some places of green shale and in others of sandstone containing thin beds of green shale. It is not known to contain woolrock.

JOACHIM LIMESTONE

The Joachim limestone is exposed only in a limited tract near and north of Dogtown Landing in southwestern Calhoun County. It varies somewhat in composition from bed to bed but as a unit is a relatively pure magnesian limestone. The formation is not known to contain woolrock.

PLATTIN LIMESTONE

The Plattin limestone crops out in the Mississippi River bluffs of Calhoun County in places from Dogtown Landing north to a point west of Batchtown, a distance of about 3½ miles. The individual beds of the formation vary in composition but as a whole the formation is a somewhat magnesian limestone. It is not known to contain woolrock.

PLATTEVILLE LIMESTONE

The Platteville limestone is exposed at numerous places in northern Illinois, particularly in Lee and Ogle counties and to a lesser extent in Stephenson, Winnebago, and JoDaviess counties. The formation is of variable nature, including comparatively pure limestone and magnesian limestone. In LaSalle, Grundy, Kendall, and Kane counties the Platteville is not distinguished from the Galena formation. The Platteville formation is not known to contain woolrock.

KIMMSWICK LIMESTONE

The Kimmswick limestone crops out locally in the bluffs and uplands of western Calhoun County from a point two miles north of Batchtown south to Dogtown Landing. Limited exposures also occur in southwestern Jersey County, at Valmeyer in Monroe County, and near Thebes in Alexander County. The formation is characteristically a limestone of high purity and is not known to contain woolrock.

GALENA DOLOMITE

The Galena dolomite outcrops in places throughout most of the Ordovician area in northern Illinois. It is most widely exposed in JoDaviess, Stephenson, Winnebago, Carroll, Lee, and Ogle counties. The formation is comparatively pure dolomite in places but is locally cherty or argillaceous. In LaSalle, Grundy, Kendall, and Kane counties the Galena formation is not distinguished from the Platteville. Locally the argillaceous or highly cherty dolomite may be a woolrock.

MAQUOKETA-RICHMOND STRATA

Strata of Maquoketa-Richmond age underlie and crop out locally in a belt 4 to 8 miles wide along both the east and west margins of the Ordovician area in northern Illinois. In JoDaviess and southwestern Stephenson counties the formation is exposed at many places throughout the entire area. It underlies parts of the uplands and locally crops out in the bluffs of western Calhoun County roughly from Beechville to within about 1½ miles of Hamburg. Other limited outcrop areas occur in the vicinity of Valmeyer, Monroe County, and in southwest Jersey County.

In northern Illinois the formation is characteristically shale, some of which is calcareous or interbedded with limestone strata. Locally limestone or dolomite beds as much as 30 feet thick are known. Some of the interbedded limestone and shale, the calcareous or dolomitic shale and the impure limestone or dolomite is woolrock or sub-woolrock in places.

In Alexander County the Fernvale limestone, the Thebes sandstone, and the Orchard Creek shale are of Maquoketa-Richmond age. The Fernvale limestone also occurs below the shale phase of the Maquoketa formation in Monroe County. The Fernvale formation is thin and unimportant as a rock wool making material. The Thebes sandstone is firmly cemented and fine grained. It is not a woolrock. The Orchard Creek shale is thin and is not known to contain rock wool making material.

Silurian System

Outcrops of the Silurian system are confined to the northeastern and northwestern parts of the State with the exception of limited areas in Calhoun and Jersey counties in western Illinois and Alexander County in southern Illinois. The major units comprising the system are the Alexandrian series and the Niagaran series.

ALEXANDRIAN SERIES

The Alexandrian series consists of a number of different formations, most of them less than 40 feet thick, including limestone, shale, sandstone, and dolomite. These are exposed locally in a belt along the western margin of the Silurian area in northeastern Illinois, at many places in northwestern Illinois, in Calhoun, Pike, and southwestern Jersey counties, and in Alexander County. Locally some of the limestones or dolomites are impure and may be sub-woolrocks.

NIAGARAN SERIES

The Niagaran series is comprised of a number of different kinds of dolomite. Strata as much as 50 feet thick are of high purity; similar thicknesses are cherty, and locally sandy or clayey strata are present. Niagaran rocks crop out at many places in Cook, Will, Kane, DuPage, and Kankakee counties and are extensively quarried at Chicago and in the vicinity of Joliet and Kankakee.

The Niagaran strata are also well exposed in parts of Carroll, Whiteside, and JoDaviess counties, especially in the bluffs of Mississippi River.

In southern Calhoun and southwestern Jersey counties the Niagaran dolomite is exposed in several places, particularly near Hardin. In places it is a limestone.

Locally some of the impure dolomite and some of the highly cherty dolomite of the Niagaran formation is woolrock or sub-woolrock.

Devonian System

Rocks of the Devonian system crop out in three comparatively limited areas along the west edge of the State in Rock Island, Calhoun, Alexander and Union counties. In Rock Island County roughly the upper half of the Devonian sediments are limestone and dolomite, locally shaly and impure. Some of these beds are sub-woolrock. The lower Devonian beds are mainly comparatively pure limestone.

In Calhoun County the exposed Devonian is probably the Cedar Valley formation. Outcrops, mostly small, occur in that part of the county between Hamburg and Beechville. The formation is limestone. A thin sandy limestone of Devonian age crops out locally in southwestern Jersey County. No woolrock is known to be present.

The Devonian system in Alexander and Union counties is comprised dominantly of the Bailey limestone and two thick chert and cherty limestone formations—the Clear Creek and Grassy Knob—together with several other, mostly thin limestone or shale formations. The chert formations as observed in many outcrops are mostly devoid of carbonates but may be calcareous at some places. The Bailey formation is a highly cherty, impure limestone. Outcrops are comparatively numerous throughout the area mapped, especially in the Mississippi River bluffs and the vicinity. The Bailey limestone is probably generally a woolrock or sub-woolrock. The chert formations are not known to be woolrocks but locally may be sub-woolrocks.

The small outcrop area of Devonian in Hardin County is underlain largely by shale and cherty limestone. The Devonian strata in eastern Illinois are everywhere covered by a thick mantle of glacial drift.

Mississippian System

Rocks of the Mississippian system crop out extensively in the western and southern portions of the State. They include a wide variety of limestone, shale, and sandstone and for convenience are divided into two units, the lower and upper Mississippian.

The lower Mississippian is divisible into three groups, in ascending order the Kinderhook, the Osage, and the Meramec. The first is mostly shale with minor amounts of limestone. In western Illinois the dominant formations are the Chouteau limestone and the Hannibal shale; in southern Illinois the Springville and Mountain Glen shale formations are outstanding. The Osage group is comprised of limestone, most of it cherty. In general the chert occurs in a limestone known as the Keokuk-Burlington limestone which is otherwise of high purity. The Meramec group is composed of the Warsaw, Salem, St. Louis, and Ste. Genevieve formations which are largely limestone. In places, especially in western Illinois, impure or dolomitic limestones or interbedded limestone and shale are present, particularly in the Warsaw and Salem formations. The major areas of outcrop are shown in figure 14.

The lower Mississippian limestones are generally comparatively pure. The limestones and shales individually are commonly not woolrocks though units of interbedded limestone and shale may have the chemical composition of woolrock at some places. Of the lower Mississippian formations the Warsaw is most likely to contain woolrock or sub-woolrock locally, though the Salem also is likely to contain similar materials in western Illinois.

The upper Mississippian or Chester series, where fully developed, consists of 16 formations of which 8 are dominantly limestone and 8 mostly sandstone. The limestones are frequently shaly and vary from impure to pure. No dolomitic beds are known. Outcrops of the upper Mississippian rocks are restricted to southern Illinois.

The Chester limestones are variable, ranging from pure to comparatively impure. Locally some of the Chester limestones may be sufficiently impure or interbedded with the right proportion of shale to be sub-woolrocks or woolrocks.

Pennsylvanian System[3]

The Pennsylvanian system embraces those strata associated with the coal beds of the State. The exposed rocks of the system are dominantly shale and sandstone but include also limestones, which with a few exceptions are generally less than 5 feet thick, and therefore are probably too thin to be of importance as commercial sources of raw material for rock wool manufacture except under unusual circumstances. The four most persistently thick beds are the Brereton limestone or cap limestone of coal No. 6, the Shoal Creek, the LaSalle, and the Omega limestones. However, other normally thin beds thicken locally to such an extent that they are prominent in certain areas.

The Pennsylvanian limestones are characteristically variable in thickness and composition though some beds vary less than others. Some strata are usually impure, others are characteristically pure.

CAPROCK OF COAL NO. 6 (BRERETON LIMESTONE)

The Brereton limestone is highly variable in character and thickness, ranging from a few inches to 20 feet or more. Chemically it ranges from a highly impure siliceous limestone to one containing more than 90 per cent carbonates. It is extensively exposed, especially in strip coal mines in southern Illinois, particularly in Perry, Jackson, Williamson, and St. Clair counties, where it is thickest and best developed. It also attains a thickness of 25 feet in subsurface mines in Macoupin and Madison counties. Where impure it is locally a woolrock or sub-woolrock.

SHOAL CREEK LIMESTONE

The approximate line of outcrop of the Shoal Creek limestone is shown in figure 14. This formation ranges from a few inches up to 10 feet in thickness. According to recent correlations[4] the Shoal Creek limestone is the same formation as the Carlinville limestone of Macoupin County and the New Haven limestone of the Wabash Valley mentioned in earlier reports. Limited chemical data regarding the Shoal Creek limestone suggest that it is locally a somewhat impure limestone but it is not known to be a woolrock.

LASALLE LIMESTONE

The LaSalle limestone crops out at numerous places throughout the State (Fig. 14). In LaSalle County it ranges up to 30 feet in thickness and is extensively used for making Portland cement. It commonly contains a thin bed of shale which divides it into two benches. A similar shale parting is present locally in Clark County where the formation is roughly 10 to

[3] Data regarding correlation and distribution of limestones: J. M. Weller and H. R. Wanless, personal communication.

[4] Ekblaw, S. E., The question of the Shoal Creek and Carlinville limestones: Trans. Illinois State Acad. Sci., Vol. 25, No. 4, p. 143, 1933.

35 feet thick and has been variously known as the Livingston, Marshall, Casey, or Quarry Creek limestone.

In the Gillespie-Mt. Olive region the LaSalle, formerly identified as the Shoal Creek limestone, is comprised of a series of more or less impure beds of limestone and is 12 to 25 feet thick. The LaSalle formation also embraces the 16- to 20-foot limestone in Vermilion County called the Fairmont limestone, the Baldwinsville limestone of Edgar County, and the Ryans Ford limestone of Coles and Cumberland counties.

The composition of the LaSalle limestone at various places is given in Table 12. Locally it is woolrock or sub-woolrock but in general it is too pure to be used by itself for making rock wool.

OMEGA LIMESTONE

The approximate line of outcrop of the Omega limestone is shown in figure 14. Its thickness ranges from less than a foot to a known maximum of 17 feet and usually averages 3 to 4 feet or more. Information regarding its composition is scanty but from the data at hand it is thought to be characteristically a pure limestone.

OTHER LOCALLY THICK LIMESTONES

The "blue rock" lying above the Rock Island No. 1 coal in Rock Island, Mercer, and Warren counties reaches a thickness of 20 feet in places. Limited data at hand suggest that it is for the most part more a calcareous shale than a limestone. Locally the "blue rock" may be a sub-woolrock.

In Fulton County the Seville limestone which lies above Rock Island (No. 1) coal locally reaches a thickness of 5 to 20 feet though in places it is absent. For the most part it is probably a fairly pure limestone according to the information at hand. In southeastern Illinois an equivalent bed known as the Curlew limestone is locally 10 to 20 feet thick but is usually very cherty.

The Seahorne limestone which lies some distance below coal No. 2 locally reaches a thickness of 8 feet, as near Frederick in Schuyler County where it is a comparatively pure limestone.

The Piasa limestone overlies No. 7 coal or its horizon and is 5 to 6 feet thick in places in Jersey County. It is a relatively pure limestone so far as is known.

The Lonsdale limestone is locally 15 to 20 feet thick near Peoria and 5 to 15 feet thick in Stark County and near Sparland in Marshall County. It varies in composition from comparatively pure to impure limestone. Locally it is a sub-woolrock.

The St. David limestone is 6 feet thick locally in St. Clair County and lies between coal No. 6 and the Belleville (No. 5) coal. One test shows it to be an impure limestone.

ISGS B 61 - Rock wool

The Macoupin limestone, also known as the Crows Mill limestone, is 4 to 7 feet thick locally in Sangamon County where one analysis shows it to be an impure limestone.

The Pontiac limestone outcrops at a number of places in the vicinity of Pontiac, Livingston County, and is mostly a comparatively pure limestone 10 to 20 feet thick.

PENNSYLVANIAN SHALE AND CLAY

Shale and clay are among the most common sediments of the Pennsylvanian system of rocks and crop out at some places in a large percentage of those counties underlain by this system. The shales vary considerably in composition and many of them are somewhat calcareous. Those shales that are not distinctly limy have a composition which falls reasonably close to the following average. This average is compiled from analyses of Illinois shales used for making brick, tile, etc. The range in composition shown by the analyses is also given.

Table 9—*Average composition and range in composition of Illinois shales*

	Number of analyses averaged	Average	Maximum in samples averaged	Minimum in samples averaged
		Per cent	*Per cent*	*Per cent*
SiO_2	18	59.81	65.89	46.49
Al_2O_3	18	17.93	24.43	12.64
Fe_2O_3	18	7.39	13.56	4.52
MgO	18	1.94	2.75	0.65
CaO	18	1.11	2.22	0.31
K_2O	9	2.88	3.82	2.03
Na_2O	9	0.88	1.50	0.18
Ignition	18	6.79	11.60	4.56
Moisture	13	1.13	3.70	0.20
S	9	0.19	0.32	0.11
		100.05		

The clays of the Pennsylvanian system occur commonly below coal beds or below the horizon of these beds where the coal is absent. The underclays are commonly calcareous except for a thickness of a few inches or feet immediately below the coal overlying them. Exceptions to the foregoing are the underclays that occur in the series of Pennsylvanian beds below No. 2 coal in north, west, and southwestern Illinois. Some of these underclays are noncalcareous in many places though locally they are limy; characteristically limy underclays are also present.

The table below gives data on the composition of Illinois underclays. This table does not include the Pennsylvanian clays in western Calhoun and southern Pike counties which may be underclays but are not now directly associated with coal beds. The analyses are of noncalcareous underclays.

TABLE 10—*Average composition and range in composition of Illinois underclays*

	Number of analyses averaged	Average	Maximum in samples averaged	Minimum in samples averaged
		Per cent	*Per cent*	*Per cent*
SiO_2	13	59.63	67.37	53.19
Al_2O_3	13	24.70	29.49	21.00
Fe_2O_3	13	2.62	4.77	1.57
MgO	5	1.58	2.61	0.80
CaO	5	0.82	1.93	0.16
CO_2	5	0.34	1.37	0.00
Ignition	13	8.72	12.52	6.17
Moisture	8	1.62	2.37	1.25
		100.03		

CRETACEOUS-TERTIARY SYSTEMS

Clay, silt, sand and chert gravel of Cretaceous-Tertiary age crop out at many places in Alexander, Pulaski, and Massac counties in extreme southern Illinois and at a few places in western Illinois. These sediments are not known to include materials potentially valuable by themselves for making rock wool. They may possibly be of interest for mixing with other materials. All available analyses are given in Table 12 (p. 154).

PLEISTOCENE SYSTEM

The Pleistocene sediments of Illinois are unconsolidated materials such as gravel, sand, silt, and clay and commonly cover the bedrock in most parts of the State. Locally some deposits of these sediments have the chemical composition of woolrock. Their distribution and potential value as rock wool making materials is discussed in the preceeding chapter (Chapter IV). Analysis of typical Pleistocene materials are given in Tables 7 and 8 (pp. 122, 126).

TABLE 11—*Results of CO_2 determinations (not given elsewhere) on samples tested but found to be unsuitable for making rock wool without the addition of other materials*

County	Sample No.	Location						Near	Thickness sampled (feet)	CO_2 (a)	Formation
		T.	R.	Sec.	¼	¼	¼				
Limestone and Dolomite											
Adams.	DS-50	2S	9W	23	. . . . . .	W½	NE	Quincy.	20	43.5	Burlington limestone
Clark.	DS-106	11N	12W	1	. . . . . .	S½	NE	Marshall.	7	41.4	Livingston limestone
Calhoun. . . .	DS-40	12S	2W	19	. . . . . .	NE	SE	Batchtown.	75	43.2	Joachim-Plattin limestone
Calhoun. . . .	DS-42	12S	2W	1	NE	SW	NE	Golden Eagle.	8	42.6	Carbondale limestone
Fulton.	DS-53	8N	4E	9	SW	NE	NW	Farmington.	6	39.2	Limestone over coal No. 6
JoDaviess. . .	DS-70s	27N	1E	21	SE	NW	SE	Galena.	45	44.4	Galena dolomite
Johnson. . . .	DS-21	12S	3E	22	NE	SW	SW	Bloomfield.	16	41.3	Kinkaid limestone
Kankakee. . .	NF-97	30N	14W	7	NE	SW	NW	Kankakee.	24	43.67	Niagaran dolomite
Kankakee. . .	NF-98	30N	14W	7	NE	SW	NW	Kankakee.	18	42.86	Niagaran dolomite
LaSalle.	DS-63	32N	2E	8	SE	NE	SE	Lowell.	55	43.9	Galena dolomite
Lee.	DS-70d	22N	9E	27	SE	SE	NW	Dixon.	35	41.0	Platteville limestone
Massac.	DS-28	14S	3E	22	SE	SE	NE	Mermet.	20	43.1	Ste. Genevieve limestone
Pike.	DS-48	4S	7W	24	. . . . . .	SE	NW	Kinderhook.	9	37.70	Burlington limestone
Stephenson. .	DS-75	28N	6E	29	NW	SE	NW	Lena.	12	45.4	Galena dolomite
Union.	DS-9	13S	2W	1	W½	SW	SE	Jonesboro.	12	42.4	Warsaw-Salem limestone

Bedrock Clay and Shale

Clark.......	DS-105	11N	12W	1	......	S½	NE	Marshall..........	22	6.2	Shale over LaSalle limestone
Clark......	DS-109	11N	11W	8	NW	SE	SE	Marshall..........	20	3.6	Shale below LaSalle limestone
Crawford...	DS-108	5N	11W	19	SW	NE	NE	Flat Rock.........	20	4.8	McLeansboro shale
Jackson.....	DS-20	7S	1W	19	SE	NW	NE	DeSoto...........	12	3.1	Shale above coal No. 6
LaSalle.....	DS-60	32N	2E	9	SE	SE	SW	Lowell...........	4	7.4	Underclay of coal No. 2
LaSalle.....	DS-61	32N	2E	9	SE	SE	SW	Lowell...........	6	2.9	Underclay of coal No. 2
LaSalle.....	DS-64	32N	2E	8	Cen.	......	S½	Lowell...........	31	3.2	"Coal Measures" shale
LaSalle.....	DS-65	32N	2E	8	Cen.	......	S½	Lowell...........	39	10.1	Shale over coal No. 2
Pope.......	DS-25	12S	5E	19	SW	NW	SE	Simpson..........	12	3.4	Clore shale
Rock Island.	DS-66	17N	1W	26	SW	SE	SW	Coal Valley........	10	2.4	"Coal Measures" shale
Union......	DS-1	12S	2W	23	SE	NW	NE	Jonesboro.........	13	3.9	Springville shale
Union......	DS-8	13S	2W	1	SW	SW	SE	Jonesboro.........	56	6.1	Springville shale
Vermilion...	DS-104	19N	11W	7	......	W½	SE	Danville..........	....	3.1	"Coal Measures" shale
Will........	DS-96	33N	9E	32	......	......	SE	Wilmington.......	33	3.0	Shale over coal No. 2
Will.......	NF-53	35N	10E	21	......	NE	SE	Joliet............	6	3.5	Clay pocket in Niagaran dolomite

Miscellaneous

Pike.......	DS-49	4S	7W	24	......	SE	NW	Kinderhook.......	36	5.94 (*b*)	Hannibal siltstone
Union......	NF-72	12S	2W	36	NE	NW	SE	Jonesboro.........	12	1.0	Springville chert

(*a*) CO_2 approximated by loss on ignition between 400-1000°C.
(*b*) Analytically determined CO_2.

TABLE 12—*Typical analyses of Illinois limestones,*

ORDOVICIAN SYSTEM

Limestone and Dolomite

County	Formation	Sample No.	Reference	Location T	R	Sec.	¼	¼	Near	Thickness sampled (feet)
Alexander	Kimmswick	----------	(*b*)	15S	3W	17	------	NE	Thebes	70
Boone	Galena	----------	(*b*)	44N	3E	34	SW	NE	Belvidere	38?
Calhoun	Joachim	R-18	(*d*)	12S	2W	19	SW	SE	Brussels	60
Calhoun	Kimmswick	R-29	(*d*)	12S	2W	17	NW	SE	Batchtown	37
Calhoun	Plattin	R-19	(*d*)	12S	2W	19	S½	N½	Brussels	50
Carroll	Galena	----------	(*c*)	------	------	------	------	------	Mt. Carroll	----------
Kane	Maquoketa	NF-46	(*e*)	40N	8E	10	NW	NW	Elgin	6½
LaSalle	Galena-Platteville	W-80	(*e*)	33N	3E	21	NE	SE	Ottawa	13
LaSalle	Galena-Platteville	DS-63	(*e*)	32N	2E	8	NE	SE	Lowell	50
LaSalle	Shakopee	DS-56	(*e*)	33N	2E	17	------	NE	Utica	11
LaSalle	Shakopee	DS-18	(*e*)	33N	2E	7	SE	SE	Utica	26
LaSalle	Shakopee	DX-19	(*e*)	33N	2E	7	SE	SE	Utica	40
LaSalle	Shakopee	DS-57	(*e*)	33N	2E	8	NE	SW	Utica	60
LaSalle	Shakopee	C-14a	(*f*)	33N	2E	8	SW	SW	Utica	7
LaSalle	Shakopee	C-14b	(*f*)	33N	2E	8	SW	SW	Utica	13
Lee	Platteville	----------	(*f*)	22N	9E	27	------	SW	Dixon	----------
Lee	Platteville	L-188	(*c*)	22N	9E	21	SE	SW	Dixon	50
Monroe	Decorah or Plattin	NF-89	(*e*)	3S	11W	3	NE	SW	Valmeyer	11
Monroe	Kimmswick	L-68	(*c*)	3S	11W	3	------	SW	Valmeyer	----------
Ogle	Galena	NF-140	(*e*)	25N	9E	21	SW	SW	Adeline	55
Ogle	Galena	NF-135	(*e*)	24N	9E	32	SW	SE	Mt. Morris	50
Ogle	Platteville	L-190	(*c*)	22N	9E	8	NW	NW	Grand Detour	40
Ogle	Platteville	C-7d	(*f*)	23N	9E	27	------	SE	Grand Detour	10
Stephenson	Galena	DS-75	(*e*)	28N	6E	29	SE	NW	Lena	12
Stephenson	Maquoketa	DS-74	(*e*)	28N	5E	13	SE	SE	Waddams Grove	35
Stephenson	Maquoketa	DS-77	(*e*)	26N	6E	6	SE	SE	Pearl City	26
Stephenson	Platteville	C-1a	(*f*)	29N	6E	22	NW	SE	Winslow	2
Stephenson	Platteville	C-1b,c,	(*f*)	29N	6E	22	------	------	Winslow	31?
Will	Maquoketa	----------	(*c*)	------	------	------	------	------	Wilmington	----------
Winnebago	Galena	----------	(*c*)	44N	1E	15	SW	SE	Rockford	----------

Shale

County	Formation	Sample No.	Reference	T	R	Sec.	¼	¼	Near	Thickness sampled (feet)
Calhoun	Maquoketa	R-7	(*d*)	11S	2W	17	NE	SW	Gilead	16
Carroll	Maquoketa	H-20	(*h*)	------	------	------	------	------	Savanna	----------
JoDaviess	Maquoketa	H-21	(*h*)	------	------	------	------	------	Rodden	----------
Kane	Maquoketa	DS-98	(*e*)	40N	8E	10	NW	NW	Elgin	5
Monroe	Maquoketa	S-22	(*b*)	3S	11W	10	NE	NW	Valmeyer	22
Stephenson	Maquoketa	DS-76	(*e*)	26N	6E	1	NE	SE	Pearl City	12
Whiteside	Maquoketa	H-18	(*h*)	------	------	------	------	------	Sterling	----------

SILURIAN SYSTEM

ALEXANDRIAN SERIES

Limestone and Dolomite

County	Formation	Sample No.	Reference	T	R	Sec.	¼	¼	Near	Thickness sampled (feet)
Alexander	Girardeau	L-37	(*b*)	15S	3W	21	NE	NW	Thebes	25
Boone	Edgewood	DS-78	(*e*)	43N	3E	14	SW	NW	Belvidere	6
Boone	Edgewood	DS-79	(*e*)	43N	3E	14	SW	NW	Belvidere	10
Jersey	Sexton Creek	R-13	(*e*)	8N	13W	29	SE	NE	E. Hardin	8
Will	Kankakee	NF-54	(*e*)	35N	10E	21	NE	SE	Joliet	35
Will	Kankakee	DS-97	(*e*)	33N	10E	31	NE	NE	Wilmington	12
Will	Kankakee	----------	(*c*)	33N	10E	31	NW	NE	Wilmington	----------
Will	Kankakee	NF-56	(*e*)	35N	10E	21	NE	SE	Joliet	1

Shale

County	Formation	Sample No.	Reference	T	R	Sec.	¼	¼	Near	Thickness sampled (feet)
Alexander	Sexton Creek	DS-7	(*e*)	15S	3W	28	SE	SE	Thebes	18

dolomites, shales, silts and sands (a)

ORDOVICIAN SYSTEM

Limestone and Dolomite

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O—	Loss on ignition 110°–400°C	Loss on ignition 400°–1000°C	Loss on ignition	Miscellaneous
97.33	0.15	*54.50*	*0.24*	0.47	0.19	0.17	-----	-----	-----	-----	-----	-----	-----	-----	-----	Average 3 analyses
53.43	43.00	*29.92*	*20.55*	2.39	-----	-----	0.92	-----	-----	-----	-----	-----	-----	-----	-----	Average 2 analyses
61.19	*34.27*	34.28	16.39	3.54	0.60	0.94	-----	-----	-----	-----	-----	-----	-----	-----	43.83	SO_3–0.14
99.10	*0.88*	55.52	0.42	0.74	0.28	0.62	-----	-----	-----	-----	-----	-----	-----	-----	42.67	SO_3–0.10
86.41	*11.19*	48.41	5.35	2.19	0.72	0.46	-----	-----	-----	-----	-----	-----	-----	-----	43.01	SO_3–0.26
54.06	43.68	*30.27*	*20.88*	1.62	-----	-----	1.12	-----	-----	-----	-----	-----	-----	-----	-----	
29.6	*24.3*	16.6	11.6	29.4	10.58	2.92	-----	-----	-----	-----	-----	2.54	1.2	24.6	-----	Na_2O+K_2O as K_2O–3.2
78.06	*17.38*	43.73	8.31	0.80	1.19	1.67	-----	0.00	Trace	Trace	43.72	0.02	-----	-----	44.13	S–0.12
-----	-----	-----	-----	0.60	-----	-----	-----	-----	-----	-----	43.85	-----	-----	-----	-----	
-----	-----	-----	-----	11.59	-----	-----	-----	-----	-----	-----	39.70	-----	-----	-----	-----	
42.93	*29.23*	24.05	13.98	16.10	6.57	1.60	-----	-----	-----	-----		-----	-----	37.01	37.43	
42.36	*33.94*	23.73	16.23	23.05	1.64	1.64	-----	-----	-----	-----	-----	0.01	0.36	34.48	34.85	
45.37	*39.50*	25.42	18.89	12.65	1.58	1.18	-----	-----	-----	-----	39.46	0.10	-----	-----	39.60	
45.34	26.14	25.40	12.50	15.02	-----	-----	8.20	-----	-----	-----	-----	0.33	-----	-----	38.54	
46.61	20.53	26.12	9.82	14.42	-----	-----	11.34	-----	-----	-----	-----	0.12	-----	-----	38.80	
85.61	4.28	47.98	2.05	5.28	-----	-----	3.62	-----	-----	-----	-----	0.17	-----	-----	41.36	Average 5 analyses
56.60	42.18	*31.75*	*20.16*	0.84	-----	-----	2.10	-----	-----	-----	-----	-----	-----	-----	-----	
56.0	*1.6*	31.4	0.8	40.2	0.33	2.07	-----	-----	-----	-----	-----	0.0	0.0	24.6	-----	
95.70	3.46	*53.69*	*1.65*	0.08	-----	-----	0.74	-----	-----	-----	-----	-----	-----	-----	-----	
55.82	*45.21*	31.27	21.62	0.23	0.07	0.44	-----	-----	-----	-----	46.59	0.00	-----	-----	46.91	
54.76	*42.24*	30.68	20.20	1.09	0.40	0.60	-----	-----	-----	-----	46.35	0.00	-----	-----	46.89	
76.36	19.16	*42.76*	*9.16*	3.10	-----	-----	2.30	-----	-----	-----	-----	-----	-----	-----	-----	
86.36	11.41	48.40	5.46	1.38	-----	-----	1.56	-----	-----	-----	-----	0.19	-----	-----	43.98	
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	45.53	-----	
31.11	*24.28*	17.43	11.61	29.66	-----	-----	13.14	-----	-----	-----	-----	0.75	1.11	27.21	-----	
45.93	*34.79*	25.73	16.64	11.74	4.82	1.29	-----	-----	-----	-----	36.90	0.14	-----	-----	39.51	
46.71	33.90	26.18	16.22	14.02	-----	-----	3.52	-----	-----	-----	-----	0.12	-----	-----	40.78	
54.80	40.12	30.71	19.19	1.90	-----	-----	1.62	-----	-----	-----	-----	0.12	-----	-----	41.72	Average 2 analyses
76.9	5.2	43.05	2.51	13.58	-----	-----	2.38	-----	-----	-----	-----	-----	-----	-----	36.99	
53.00	43.00	*29.68*	*20.55*	2.00	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Other ingredients–2.00

Shale

-----	-----	2.81	1.80	56.69	23.31	6.05	-----	-----	-----	-----	-----	-----	-----	-----	7.92	SO_3–0.14
-----	-----	7.33	6.19	47.29	15.51	4.80	-----	-----	-----	-----	-----	1.31	-----	-----	13.11	Na_2O+K_2O–3.71
-----	-----	5.73	3.13	48.41	18.31	6.06	-----	-----	-----	-----	-----	0.79	-----	-----	12.79	Na_2O+K_2O–5.65
30.31	*15.93*	16.98	7.62	40.75	12.97	3.56	-----	-----	-----	-----	14.81	0.79	-----	-----	17.87	
27.10	*4.98*	15.18	2.38	56.40	7.09	4.46	-----	-----	-----	-----	-----	-----	-----	-----	14.36	SO_3–0.00
-----	-----	9.74	5.38	44.97	16.23	5.46	-----	-----	-----	-----	12.42	0.86	-----	-----	18.00	
-----	-----	7.57	5.08	39.91	16.43	4.80	-----	-----	-----	-----	-----	0.86	-----	-----	21.20	Na_2O+K_2O–3.71

SILURIAN SYSTEM

ALEXANDRIAN SERIES

Limestone and Dolomite

89.20	0.98	*49.97*	0.47	4.42	0.11	0.37	-----	-----	-----	-----	-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	39.30	-----	
44.82	*30.90*	25.11	14.78	12.66	6.35	1.52	-----	-----	-----	-----	38.39	0.24	-----	-----	39.47	
96.27	*1.25*	53.93	0.60	2.10	0.48	0.32	-----	-----	-----	-----	-----	-----	-----	-----	42.70	SO_3–0.14
50.87	*40.77*	28.5	19.5	7.8	-----	-----	2.6	-----	-----	-----	-----	0.06	0.3	42.4	-----	
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	41.84	-----	-----	-----	-----	
86.25	*4.85*	48.32	2.19	8.11	-----	-----	3.51	-----	-----	-----	-----	-----	-----	-----	38.54	
21.96	*34.71*	12.3	16.6	33.4	9.01	1.99	-----	-----	-----	-----	-----	0.90	1.9	24.3	-----	MnO–0.07

Shale

-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	4.50	-----	

Table 12—*Typical analyses, Silurian system*—Continued

NIAGARAN SERIES

Limestone and Dolomite

County	Formation	Sample No.	Reference	Location						Thickness sampled (feet)
				T	R	Sec.	¼	¼	Near	
Calhoun	Niagaran	R-35	(e)	12S	2W	23	SW	SE	Meppen	22
Cook	Niagaran	NF-58	(e)	36N	13E	33	NW	SE	Thornton	40
Cook	Niagaran	NF-59	(e)	36N	14E	33	NW	SE	Thornton	30
Cook	Niagaran	NF-59a	(e)	37N	13E	36	NE	SW	Blue Island	------
Cook	Niagaran	NF-60	(e)	37N	13E	36	NE	SW	Blue Island	------
Cook	Niagaran	NF-61	(e)	37N	13E	36	NE	SW	Blue Island	------
Cook	Niagaran	NF-62	(e)	38N	12E	10	NE	SW	LaGrange	10
Cook	Niagaran	------	(c)	38N	12E	15	------	SW	McCook	------
Cook	Niagaran	------	(c)	------	------	------	------	------	Romeo	------
Cook	Niagaran	------	(c)	36N	14E	33	------	E½	Thornton	------
Cook	Niagaran	DX-5	(e)	37N	11E	21	NE	SW	Lemont	15
Cook	Niagaran	DX-4	(e)	37N	11E	21	NE	SW	Lemont	10
Jersey	Niagaran	------	(c)	------	------	------	------	------	Grafton	------
JoDaviess	Niagaran	DS-72	(e)	27N	1E	14	NW	SE	Rodden	25
Kane	Niagaran	NF-28	(e)	39N	8E	27	NW	NE	Batavia	4½
Kane	Niagaran	NF-30	(e)	39N	8E	22	NE	NE	Batavia	12
Kane	Niagaran	NF-31	(e)	39N	8E	22	NE	NE	Batavia	14
Kane	Niagaran	NF-37	(e)	39N	8E	27	NW	NE	Batavia	14½
Kane	Niagaran	NF-38	(e)	39N	8E	27	NE	SW	Batavia	9
Kane	Niagaran	NF-40	(e)	39N	8E	27	NE	SW	Batavia	7
Kane	Niagaran	NF-41	(e)	40N	8E	9	NE	NE	Elgin	12
Kane	Niagaran	NF-29	(e)	39N	8E	27	NW	NE	Batavia	7½
Kankakee	Niagaran	NF-95	(e)	30N	13W	28	SE	SW	Aroma	5½
Kankakee	Niagaran	------	(c)	30N	11E	7	------	NE	Kankakee	------
Stephenson	Niagaran	DS-73	(e)	28N	5E	13	SE	SE	Waddams Grove	30
Will	Niagaran	NF-55	(e)	35N	10E	21	NE	SE	Joliet	50
Will	Niagaran	------	(c)	35N	10E	17	SE	SE	Joliet	35
Will	Niagaran	L-111C	(c)	35N	10E	17	SE	SE	Joliet	8
Will	Niagaran	L-112	(c)	35N	10E	20	SW	SE	Joliet	40
Will	Niagaran	L-126B	(c)	32N	10E	26	------	------	Rockville	5½
Will	Niagaran	L-122	(c)	34N	10E	14	SE	NE	Manhattan	17

Shale

Kane	Niagaran	NF-39	(e)	39N	8E	27	NE	SW	Batavia	2

DEVONIAN SYSTEM

Limestone and Chert

Alexander	Clear Creek	147R	(e)	15S	3W	16	------	NE	Thebes	20
Jackson	Backbone	L-53	(b)	10S	4W	23	E½	E½	Grand Tower	45
Jackson	Backbone?	S-57a	(f)	10S	4W	25	------	NW	Grand Tower	48
Jackson	Grand Tower?	S-5	(f)	10S	4W	25	------	NE	Grand Tower	15
Jersey	Cedar Valley	R-14	(d)	8N	13W	29	NE	NE	Hardin	13
Rock Island	Devonian	------	(c)	18N	1W	34	------	------	Moline	------

TABLE 12—*Typical analyses, Silurian system*—Continued

NIAGARIAN SERIES

Limestone and Dolomite

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O-	Loss on ignition 110°-400°C	Loss on ignition 400°-1000°C	Loss on ignition	Miscellaneous
52.00	*40.29*	29.13	19.27	4.28	1.15	1.71	-----	-----	-----	-----	-----	-----	-----	-----	43.99	SO_3-0.10
46.95	*36.59*	26.3	17.5	14.6	-----	-----	4.3	-----	-----	-----	-----	0.01	0.8	37.7	-----	
53.19	*40.77*	29.8	19.5	2.4	-----	-----	1.8	-----	-----	-----	-----	0.05	1.6	45.3	-----	
30.61	*28.44*	17.15	13.60	28.86	7.39	0.84	-----	0.31	0.10	2.09	25.81	0.55	-----	-----	28.20	FeO-1.17, SO_3-0.07, S-0.29, H_2O+-1.30
31.59	*26.97*	17.7	12.9	31.2	9.15	1.95	-----	-----	-----	-----	-----	0.48	0.7	26.4	-----	
43.68	*35.07*	24.47	16.77	15.40	4.00	0.58	-----	0.20	0.06	0.69	36.32	0.05	-----	-----	36.88	FeO-0.98, SO_3-0.16, S-0.26, H_2O + -0.85
49.98	*41.19*	28.0	19.7	7.9	-----	-----	4.2	-----	-----	-----	-----	0.52	1.0	41.2	-----	
54.82	43.13	*30.70*	*20.62*	1.04	0.86	0.80	-----	-----	-----	-----	-----	-----	-----	-----	-----	Average 36 analyses
53.73	42.13	*30.09*	*20.14*	1.99	0.63	1.15	-----	-----	-----	-----	-----	-----	-----	-----	-----	P-0.014; average several analyses
54.04	42.96	*30.26*	*20.53*	1.23	0.55	0.37	-----	-----	0.19	0.14	-----	0.29	-----	-----	-----	MnO-0.03, SO_3-trace
31.22	*24.99*	17.49	11.95	41.08	2.01	1.88	-----	-----	-----	-----	-----	0.19	0.40	25.51	-----	
41.04	*31.39*	22.99	15.01	24.84	1.13	1.85	-----	-----	-----	-----	-----	0.15	0.38	34.29	-----	
47.79	42.86	*26.76*	*20.49*	5.60	-----	-----	1.40	-----	-----	-----	-----	2.35	-----	-----	-----	
41.48	*34.08*	23.24	16.30	19.66	4.27	1.56	-----	0.38	-----	-----	33.76	0.00	-----	-----	34.60	
44.02	*36.68*	24.66	17.54	14.71	3.04	0.76	-----	0.14	Trace	0.18	37.51	0.15	-----	-----	38.52	FeO-0.26, SO_3-0.08, S-0.12, H_2O+ 0.64
49.80	*43.74*	27.90	20.92	6.75	0.56	0.21	-----	0.09	0.03	0.09	43.44	0.00	-----	-----	43.85	FeO-0.18, SO_3-0.7, S-0.10, H_2O+-0.44
51.77	*41.61*	29.0	19.9	6.7	-----	-----	2.5	-----	-----	-----	-----	0.20	0.4	43.1	-----	
49.62	*40.57*	27.8	19.4	9.5	-----	-----	2.2	-----	-----	-----	-----	0.15	0.4	41.4	-----	
40.20	*38.68*	27.0	18.5	11.8	-----	-----	3.4	-----	-----	-----	-----	0.28	0.4	39.8	-----	
47.46	*38.47*	26.59	18.40	10.06	2.44	0.64	-----	0.13	0.07	0.53	40.27	0.27	-----	-----	40.82	FeO-0.60, SO_3-0.08, S-0.21, H_2O+-0.54
52.66	*42.45*	29.5	20.3	4.8	-----	-----	1.5	-----	-----	-----	-----	0.10	0.3	43.6	-----	
34.09	*28.23*	19.1	13.5	29.7	6.88	1.52	-----	-----	-----	-----	-----	1.25	0.5	28.4	-----	
40.14	*32.52*	22.49	15.55	21.02	5.41	1.70	-----	-----	-----	-----	-----	0.86	0.20	33.60	-----	
49.40	38.24	*27.66*	*18.28*	7.65	2.92	1.38	-----	-----	-----	-----	-----	-----	-----	-----	-----	Average 2 analyses
-----	-----	-----	-----	3.31	-----	-----	-----	-----	-----	-----	43.62	-----	-----	-----	-----	
53.55	*42.45*	30.0	20.3	5.3	-----	-----	1.6	-----	-----	-----	-----	0.00	1.2	43.6	-----	
48.79	39.23	*27.32*	*18.75*	8.02	-----	-----	3.71	-----	-----	-----	-----	-----	-----	-----	-----	Average 2 analyses
53.23	41.45	*29.81*	*19.81*	3.41	-----	-----	2.03	-----	-----	-----	-----	-----	-----	-----	-----	
52.76	42.78	*29.55*	*20.45*	3.08	-----	-----	1.74	-----	-----	-----	-----	-----	-----	-----	-----	
76.58	19.86	*42.88*	*9.49*	2.12	-----	-----	1.75	-----	-----	-----	-----	-----	-----	-----	-----	
91.98	4.36	*51.51*	*2.08*	2.76	-----	-----	1.00	-----	-----	-----	-----	-----	-----	-----	-----	

Shale

20.88	*18.40*	11.7	8.8	45.4	10.30	1.80	-----	-----	-----	-----	-----	0.28	0.5	18.2	-----	Na_2O+K_2O as K_2O-4.6

DEVONIAN SYSTEM

Limestone and Chert

35.2	*2.3*	19.7	1.1	56.2	-----	-----	5.4	-----	-----	-----	-----	0.45	-----	-----	17.0	
91.36	1.57	*51.16*	*0.75*	2.12	0.21	0.47	-----	-----	-----	-----	-----	-----	-----	-----	-----	
93.93	4.89	52.64	2.34	0.86	-----	-----	0.72	-----	-----	-----	-----	0.07	-----	-----	43.92	
93.21	2.63	52.24	1.26	3.08	-----	-----	1.12	-----	-----	-----	-----	0.14	-----	-----	42.62	
88.48	*1.05*	49.57	0.50	9.92	0.54	0.46	-----	-----	-----	-----	-----	-----	-----	-----	39.23	SO_3-0.12
98.04	0.44	*54.90*	*0.21*	1.46	-----	-----	0.66	-----	-----	-----	-----	-----	-----	-----	-----	

TABLE 12—*Typical analyses, Devonian system, limestone and chert*—Continued

County	Formation	Sample No.	Reference	Location						Thickness sampled (feet)
				T	R	Sec.	¼	¼	Near	
Rock Island	Devonian	Bu-15	(*f*)	17N	2W	25	SW	NE	Milan	20
Rock Island	Devonian	Bu-16	(*f*)	17N	2W	25	NW	NE	Milan	8
Rock Island	Devonian	DS-69	(*e*)	17N	2W	25	SE	NW	Milan	14
Union	Bailey	NF-91, 92	(*e*)	11S	3W	4	SW	SE	Aldridge	95
Union	Bailey	NF-93, 94	(*e*)	13S	2W	20	N½	N½	Reynoldsville	130

MISSISSIPPIAN SYSTEM

LOWER MISSISSIPPIAN

Kinderhook group

Limestone

County	Formation	Sample No.	Reference	T	R	Sec.	¼	¼	Near	Thickness sampled (feet)
Calhoun	Chouteau	R-20	(*d*)	10S	2W	27	NE	SE	Hardin	20

Shale

County	Formation	Sample No.	Reference	T	R	Sec.	¼	¼	Near	Thickness sampled (feet)
Calhoun	Hannibal	R-5	(*d*)	9S	2W	31	SW	NW	Hamburg	40
Pike	Hannibal	DS-45	(*e*)	6S	5W	36	SW	SW	Atlas	45
Union	Springville	DS-1	(*e*)	12S	2W	23	NW	NE	Jonesboro	24
Union	Springville	DS-8	(*e*)	13S	2W	1	SW	SE	Jonesboro	56

Osage group

Limestone

County	Formation	Sample No.	Reference	T	R	Sec.	¼	¼	Near	Thickness sampled (feet)
Adams	Burlington	------	(*c*)	------	------	------	------	------	Marblehead	20±
Adams	Burlington	C-15	(*f*)	2S	9W	11	------	------	Quincy	30?
Adams	Keokuk	C-16	(*f*)	1S	9W	26	------	SW	Quincy	------
Greene	Burlington	R-110	(*e*)	10N	13W	28	SW	NE	Eldred	61
Hancock	Keokuk	C-38	(*f*)	5N	8W	30	------	------	Hamilton	9
Hancock	Keokuk	C-41	(*f*)	7N	8W	16	------	SE	Niota	4
Hancock	Keokuk	C-42	(*f*)	6N	8W	12	SE	SE	Nauvoo	5
Henderson	Burlington-Keokuk	C-39	(*f*)	8N	6W	22	------	------	Lomax	------
Monroe	Osage	NF-90	(*e*)	2S	12W	35	------	SW	Valmeyer	35
Pike	Burlington	R-100, 101	(*e*)	7S	2W	10	SE	SW	Pearl	150
Schuyler	Keokuk	C-35a	(*f*)	2N	3W	17	------	NW	Camden	------
Schuyler	Keokuk	C-35b	(*f*)	2N	3W	17	------	NW	Camden	10

Meramec group

Limestone

County	Formation	Sample No.	Reference	T	R	Sec.	¼	¼	Near	Thickness sampled (feet)
Brown	St. Louis	C-27	(*f*)	1S	2W	15	SE	SE	Cooperstown	6
Brown	St. Louis	C-28	(*f*)	1S	2W	4	------	SW	Cooperstown	7½
Brown	Salem	C-18	(*f*)	2S	3W	6	------	SE	Mt. Sterling	3
Brown	Salem	C-19a	(*f*)	2S	3W	18	------	NW	Mt. Sterling	4
Brown	Salem	C-19c	(*f*)	2S	3W	18	------	NW	Mt. Sterling	20
Brown	Salem	C-21b	(*f*)	2S	3W	20	NW	SE	Versailles	9
Brown	Salem	C-20	(*f*)	2S	3W	26	------	NW	Versailles	13
Calhoun	St. Louis	R-33	(*d*)	14S	1W	6	NE	SW	Fruitland Landing	39

TABLE 12—*Typical analyses, Devonian system, limestone and chert*—Continued

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O—	Loss on ignition 110°–400°C	Loss on ignition 400°–1000°C	Loss on ignition	Miscellaneous
82.04	5.52	45.98	2.64	6.98	—	—	4.32	—	—	—	—	—	—	—	40.00	
96.67	1.21	54.18	0.58	1.66	—	—	1.16	—	—	—	—	—	—	—	43.38	
70.15	*7.84*	39.30	3.75	13.42	5.13	2.41	—	—	—	—	34.73	0.33	—	—	36.06	
50.87	*5.37*	28.50	2.57	39.46	3.59	1.11	—	—	—	—	—	0.26	0.21	24.21	—	
59.83	*5.46*	33.52	2.61	31.75	2.71	1.59	—	—	—	—	—	0.17	0.28	27.99	—	

MISSISSIPPIAN SYSTEM

LOWER MISSISSIPPIAN

Kinderhook group

Limestone

78.95	*2.74*	44.23	1.31	14.90	2.02	1.24	—	—	—	—	—	—	—	—	36.28	SO_3–0.12

Shale

—	—	1.35	2.50	69.20	15.38	4.18	—	—	—	—	—	—	—	—	5.90	SO_3–0.15
—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.33	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.93	—	
—	—	—	—	—	—	—	—	—	—	—	—	—	—	6.06	—	

Osage group

Limestone

97.59	0.96	*54.65*	*0.46*	0.39	—	—	1.00	—	—	—	—	—	—	—	—	Average 5 analyses of chert-free limestone
77.47	1.76	43.42	0.84	19.78	—	—	1.94	—	—	—	—	0.30	—	—	35.10	
86.32	1.42	48.38	0.68	9.66	—	—	1.54	—	—	—	—	0.26	—	—	39.90	
95.23	*4.16*	53.35	1.99	1.27	0.08	0.32	—	0.00	0.01	0.16	—	0.04	—	—	43.52	S–0.06; chert not included
69.16	4.18	38.76	2.00	23.24	—	—	3.34	—	—	—	—	0.28	—	—	33.40	
86.08	1.21	48.24	0.58	10.20	—	—	2.36	—	—	—	—	0.24	—	—	38.94	
74.66	5.23	41.84	2.50	16.24	—	—	3.80	—	—	—	—	0.28	—	—	35.98	
96.71	0.71	54.20	0.34	2.30	—	—	1.12	—	—	—	—	0.08	—	—	43.06	
71.8	*3.1*	40.2	1.5	24.4	—	—	1.2	—	—	—	—	0.08	0.2	32.3	—	Partly weathered
94.25	*2.32*	52.88	1.11	2.70	0.23	0.58	—	—	—	—	—	0.00	—	—	42.41	S–0.00
85.61	0.88	47.98	0.42	9.30	—	—	4.54	0.00	0.00	0.00	42.12	0.49	—	—	38.84	
64.23	14.30	36.00	6.84	15.80	—	—	5.88	—	—	—	—	0.30	—	—	36.92	

Meramec group

Limestone

87.43	3.01	49.00	1.44	6.62	—	—	2.64	—	—	—	—	0.20	—	—	40.82	
88.89	2.51	49.82	1.20	5.86	—	—	2.42	—	—	—	—	0.23	—	—	41.02	
94.39	1.34	52.90	0.64	2.96	—	—	1.46	—	—	—	—	0.16	—	—	42.70	
43.36	18.56	24.30	8.88	26.46	—	—	10.36	—	—	—	—	0.22	—	—	30.84	
89.39	0.79	50.10	0.38	7.26	—	—	2.40	—	—	—	—	0.15	—	—	40.10	
80.86	1.05	45.32	0.50	15.40	—	—	3.10	—	—	—	—	0.40	—	—	36.40	
78.30	1.13	43.88	0.54	16.90	—	—	3.06	—	—	—	—	0.31	—	—	35.98	
94.98	*1.23*	53.21	0.59	3.23	0.44	0.62	—	—	—	—	—	—	—	—	41.98	SO_3–0.10

TABLE 12—*Typical analyses, Mississippian system, Meramec group, limestone*—Continued

County	Formation	Sample No.	Reference	Location T	Location R	Location Sec.	Location ¼	Location ¼	Location Near	Thickness sampled (feet)
Hancock	St. Louis	C-40	(*f*)	7N	8W	14		NW	Niota	6
Hardin	St. Louis	W-322	(*f*)	12S	8E	27		SW	Elizabethtown	50
Jackson	Salem		(*c*)	10S	3W	24			Grand Tower	53
Johnson	Ste. Genevieve		(*c*)	14S	2E				Joppa Junction	
Johnson	Ste. Genevieve	W-304	(*f*)	14S	2E	5		SW	Belknap	58
Madison	St. Louis		(*c*)	5N	10W	11	SW	NE	Alton	
Madison	St. Louis		(*c*)	5N	10W	11	SW	NE	Alton	
Madison	St. Louis		(*c*)	5N	10W	10-11			Alton	
Madison	St. Louis		(*c*)	5N	10W				Alton	
Monroe	St. Louis	L-69	(*c*)	2S	10W	18	NW	NE	New Hanover	15±
Monroe	Ste. Genevieve	L-66	(*c*)	1S	10W	17	SE	SW	Columbia	30±
Monroe	Salem	L-70	(*c*)	3S	11W	15	NW	SE	Valmeyer	
Monroe	Salem		(*c*)	1S	10W	14	SW	SW	Columbia	
Pulaski	Warsaw-Salem	L-10	(*b*)	14S	1W	14	SW	NE	Ullin	40
Randolph	St. Louis	U-47	(*f*)	5S	9W	20			Prairie du Rocher	
Randolph	St. Louis	K-26	(*c*)	5S	9W				Prairie du Rocher	30
St. Clair	St. Louis		(*c*)	1S	10W	10		SE	Columbia	
Schuyler	St. Louis	C-34	(*f*)	2N	3W	34	SW	SW	Camden	8
Schuyler	St. Louis	C-37	(*f*)	3N	3W	27		SW	Brooklyn	8
Schuyler	Salem or St. Louis	C-31	(*f*)	1N	2W	19	NW	NW	Ripley	5
Schuyler	Salem or St. Louis	C-32	(*f*)	1N	2W	7		NW	Scott Mill	6
Union	Ste. Genevieve	D-2	(*f*)	12S	1W	20	NW	NE	Anna	20
Union	Ste. Genevieve	U-66	(*f*)	12S	1W	20	NW	NE	Anna	
Union	Salem	L-1	(*b*)	12S	2W	2		W½	Kaolin	60
Union	Warsaw-Salem	W-285	(*f*)	13S	2W	1	NE	SE	Jonesboro	40

Shale

Brown	Salem	C-19b	(*f*)	2S	3W	18		NW	Mt. Sterling	4½

UPPER MISSISSIPPIAN

Chester series

Limestone

Johnson	Kinkaid	K-29	(*c*)	12S	3E	16		S½	Bloomfield	
Johnson	Menard	T-1	(*b*)	13S	4E	1	SE	NW	Flatwoods	7
Johnson	Menard	T-5	(*b*)	13S	4E	1	SE	NW	Flatwoods	34
Johnson	Vienna	L-100	(*b*)	13S	4E	12		E½	Grantsburg	20
Monroe	Okaw	L-67	(*c*)	3S	8W	21		W½	Hecker	13
Pope	Clore	DS-24	(*e*)	12S	5E	19	NW	SE	Simpson	5
Pope	Golconda	Bu-20	(*f*)	13S	6E	26			Golconda	50
Pope	Golconda	W-319	(*f*)	13S	7E	19			Golconda	15
Pope	Menard?	D-48	(*f*)	13S	5E	31		NE	Reevesville	28
Pope	Menard?	W-311	(*f*)	13S	5E	31		NE	Reevesville	50
Randolph	Clore	S-9	(*d*)	8S	5W	18	NW	NE	Rockwood	67
Randolph	Menard	K-12A	(*c*)	12S	6W	30			Chester	
Randolph	Menard	K-13B	(*c*)	7S	6W	30		NW	Chester	
Randolph	Menard	K-13C	(*c*)	7S	6W	30		NW	Chester	
Randolph	Menard	K-13D	(*c*)	7S	6W	30		NW	Chester	
Randolph	Menard	K-17B	(*c*)	7S	6W	33		SE	Clores	
Randolph	Menard	W-208	(*f*)	7S	7W	15		NW	Menard	60
Randolph	Okaw	B-6	(*f*)	7S	7W	23			Menard	
Randolph	Okaw	K-13A	(*c*)	7S	6W	30		NW	Chester	
Randolph	Okaw	K-22	(*c*)	6S	8W	24			Reily Lake	
Randolph	Okaw	K-23	(*c*)	6S	8W	12		NW	Roots	
Randolph	Okaw	K-24A	(*c*)	6S	8W	4		SW	Roots	
Randolph	Okaw	S-1	(*d*)	7S	7W	23	NW	NE	Menard	73
Randolph	Okaw	B-8	(*f*)	7S	7W	23			Menard	
Randolph	Okaw	K-8	(*c*)	7S	7W	23	NE	NW	Menard	40
Randolph	Okaw	W-254	(*f*)	4S	8W	4		NW	Red Bud	8
Union	Paint Creek	L-20	(*b*)	12S	1W	8	N½	NE	Anna	51

TABLE 12—*Typical analyses, Mississippian system, Meramec group, limestone*—Continued

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O—	Loss on ignition 110°-400°C	Loss on ignition 400°-1000°C	Loss on ignition	Miscellaneous
95.67	0.79	53.62	0.38	2.62	-----	-----	1.48	-----	-----	-----	-----	0.13	-----	-----	42.48	
80.43	7.56	45.08	3.62	9.10	-----	-----	2.14	-----	-----	-----	-----	0.18	-----	-----	40.18	
95.30	2.09	*53.37*	*0.99*	1.34	-----	-----	1.00	-----	-----	-----	-----	-----	-----	-----	-----	Average 3 analyses
94.96	1.58	*53.18*	*0.76*	1.73	-----	-----	1.50	-----	-----	-----	-----	-----	-----	-----	-----	
94.07	3.14	52.72	1.50	2.04	-----	-----	1.22	-----	-----	-----	-----	0.12	-----	-----	43.34	
95.79	0.38	*53.64*	*0.18*	2.01	0.41	1.41	-----	-----	-----	-----	-----	-----	-----	-----	-----	
94.80	*4.18*	53.11	2.00	0.30	-----	-----	0.68	-----	-----	-----	43.30	-----	-----	-----	-----	
96.47	0.77	*54.02*	*0.37*	1.74	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	Average 7 analyses
97.53	0.44	*54.62*	*0.21*	0.48	-----	-----	0.16	-----	-----	-----	-----	1.48	-----	-----	-----	
92.50	2.97	*51.80*	*1.42*	1.32	-----	-----	2.74	-----	-----	-----	-----	-----	-----	-----	-----	
91.60	2.51	*51.30*	*1.20*	4.33	-----	-----	1.28	-----	-----	-----	-----	-----	-----	-----	-----	
95.20	2.56	*53.31*	*1.22*	1.30	-----	-----	0.62	-----	-----	-----	-----	-----	-----	-----	-----	
98.43	*0.02*	*55.12*	0.01	1.12	-----	-----	0.44	-----	-----	-----	-----	-----	-----	-----	-----	
94.72	1.50	*53.04*	*0.72*	1.66	0.35	0.23	-----	-----	-----	-----	-----	-----	-----	-----	-----	
97.85	1.38	54.84	0.66	0.58	-----	-----	0.56	-----	-----	-----	-----	0.28	-----	-----	43.98	
95.89	2.12	*53.70*	*1.01*	0.90	-----	-----	1.06	-----	-----	-----	-----	-----	-----	-----	-----	
97.30	0.48	*54.49*	*0.23*	0.90	-----	-----	1.40	-----	-----	-----	-----	-----	-----	-----	-----	
88.68	4.68	49.70	2.24	4.14	-----	-----	3.08	-----	-----	-----	-----	0.14	-----	-----	42.04	
90.29	0.88	50.60	0.42	6.58	-----	-----	2.70	-----	-----	-----	-----	0.24	-----	-----	40.66	
82.90	1.00	46.46	0.48	11.88	-----	-----	3.84	-----	-----	-----	-----	0.24	-----	-----	37.76	
75.76	2.80	42.46	1.34	15.04	-----	-----	6.44	-----	-----	-----	-----	0.18	-----	-----	35.66	
91.55	7.82	50.79	3.36	1.99	-----	-----	0.36	-----	-----	-----	-----	-----	-----	-----	-----	
95.64	2.13	53.60	1.02	1.76	-----	-----	0.92	-----	-----	-----	-----	0.12	-----	-----	43.28	
96.70	0.73	*54.15*	*0.35*	0.72	0.20	0.10	-----	-----	-----	-----	-----	-----	-----	-----	-----	
92.46	2.97	51.82	1.42	3.30	-----	-----	1.48	-----	-----	-----	-----	0.10	-----	-----	42.32	

Shale

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O—	Loss on ignition 110°-400°C	Loss on ignition 400°-1000°C	Loss on ignition	Miscellaneous
29.87	1.42	16.74	0.68	56.64	-----	-----	10.80	-----	-----	-----	-----	0.39	-----	-----	14.76	

UPPER MISSISSIPPIAN

Chester series

Limestone

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O—	Loss on ignition 110°-400°C	Loss on ignition 400°-1000°C	Loss on ignition	Miscellaneous
91.45	3.10	*51.21*	*1.48*	4.74	-----	-----	0.74	-----	-----	-----	-----	-----	-----	-----	-----	
87.29	*3.74*	48.90	1.79	5.50	3.19	1.53	-----	-----	-----	-----	-----	-----	-----	-----	-----	
77.50	*5.71*	43.42	2.73	12.30	1.53	1.79	-----	-----	-----	-----	-----	-----	-----	-----	-----	
75.52	7.49	*42.29*	*3.58*	13.02	0.57	1.33	-----	-----	-----	-----	-----	-----	-----	-----	-----	
95.70	2.50	*53.59*	*1.20*	0.81	-----	-----	0.85	-----	-----	-----	-----	-----	-----	-----	-----	
86.52	*3.85*	48.47	1.84	6.79	1.47	1.18	-----	-----	-----	-----	39.25	0.19	-----	-----	39.55	
88.75	3.68	49.74	0.93	7.66	-----	-----	2.02	-----	-----	-----	-----	0.21	-----	-----	39.85	
86.43	3.34	48.44	1.60	7.04	-----	-----	2.36	-----	-----	-----	-----	0.42	-----	-----	40.46	
87.32	2.65	48.88	1.28	10.45	-----	-----	1.14	-----	-----	-----	-----	-----	-----	-----	39.81	
87.72	2.47	49.16	1.18	7.90	-----	-----	2.74	-----	-----	-----	-----	0.27	-----	-----	40.08	
87.25	*2.13*	48.88	1.02	7.92	-----	-----	3.00	-----	-----	-----	-----	-----	-----	-----	39.19	SO_3-0.15
86.05	9.00	*48.19*	*4.30*	1.74	-----	-----	3.07	-----	-----	-----	-----	-----	-----	-----	-----	
93.27	2.98	*52.23*	*1.42*	1.04	-----	-----	2.84	-----	-----	-----	-----	-----	-----	-----	-----	
91.23	2.71	*51.09*	*1.30*	3.77	-----	-----	2.10	-----	-----	-----	-----	-----	-----	-----	-----	
95.09	2.38	*53.25*	*1.14*	1.42	-----	-----	1.16	-----	-----	-----	-----	-----	-----	-----	-----	
90.44	2.38	*50.65*	*1.14*	6.06	-----	-----	1.26	-----	-----	-----	-----	-----	-----	-----	-----	
95.37	1.44	53.45	0.69	1.85	-----	-----	1.28	-----	-----	-----	-----	0.22	-----	-----	43.08	
93.95	3.86	52.50	1.56	2.48	-----	-----	1.11	-----	-----	-----	-----	-----	-----	-----	-----	
94.98	2.12	*53.19*	*1.01*	1.52	-----	-----	1.20	-----	-----	-----	-----	-----	-----	-----	-----	
94.48	2.48	*52.91*	*1.19*	1.75	-----	-----	1.43	-----	-----	-----	-----	-----	-----	-----	-----	
87.66	5.00	*49.09*	*2.39*	4.52	-----	-----	2.78	-----	-----	-----	-----	-----	-----	-----	-----	
84.95	2.48	*47.57*	*1.19*	10.84	-----	-----	1.54	-----	-----	-----	-----	-----	-----	-----	-----	
87.05	*2.11*	48.77	1.01	8.68	-----	-----	2.39	-----	-----	-----	-----	-----	-----	-----	39.65	SO_3-0.11
95.72	3.22	53.55	1.30	1.90	-----	-----	0.67	-----	-----	-----	-----	-----	-----	-----	43.68	
93.45	1.86	*52.33*	*0.89*	3.62	-----	-----	1.00	-----	-----	-----	-----	-----	-----	-----	-----	
96.42	1.09	54.04	0.52	1.50	-----	-----	2.00	-----	-----	-----	-----	0.13	-----	-----	42.72	
87.56	4.00	*49.03*	*1.91*	7.34	0.42	0.64	-----	-----	-----	-----	-----	-----	-----	-----	-----	

TABLE 12—*Typical analyses, Mississippian system, Chester series*—Continued

County	Formation	Sample No.	Reference	Location						Thickness sampled (feet)
				T	R	Sec.	¼	¼	Near	
Shale										
Johnson	Menard	T-2	(*b*)	13S	4E	1	SE	NW	Flatwoods	4
Randolph	Menard	S-14	(*b*)	7S	7W	15	NE	NW	Menard	29
Randolph	Okaw	S-3	(*b*)	7S	7W	23	NW	NE	Menard	3
Union	Renault	L-16	(*b*)	12S	1W	9	NE	SW	Anna	16

PENNSYLVANIAN ("COAL MEASURES") SYSTEM

Limestone

County	Formation	Sample No.	Reference	T	R	Sec.	¼	¼	Near	Thickness sampled (feet)
Bureau	LaSalle	C-11a	(*f*)	16N	11E	33	SW	NE	Spring Valley	8
Bureau	LaSalle	DX-17	(*e*)	16N	11E	33	NW	SW	Spring Valley	17
Bureau	LaSalle	E-15a	(*f*)	16N	11E	31			Marquette	7
Calhoun	Hanover and Brereton	R-34	(*d*)	13S	2W	14	SW	SW	Brussels	13
Clark	LaSalle	S-9	(*f*)	10N	14W	28		NE	Casey	15
Clark	LaSalle	S-51a	(*f*)	11N	11W	6		NW	Marshall	8
Clark	LaSalle	S-51c	(*f*)	11N	11W	6		NW	Marshall	6
Clark	LaSalle	S-52a	(*f*)	11N	11W	29		NW	Marshall	5
Clark	LaSalle	S-52b	(*f*)	11N	11W	29		NW	Marshall	5½
Coles	LaSalle	S-3	(*f*)	12N	10E	5		NW	Charleston	18
Edgar	LaSalle	Bu-2	(*f*)	15N	12W	3		NE	Cherry Point	
Edgar	LaSalle	S-50a	(*f*)						Baldwinsville	6
Edgar	LaSalle	S-50c	(*f*)						Baldwinsville	6
LaSalle	McLeansboro	C-13	(*f*)	33N	1E	30		SW	Peru	4
LaSalle	LaSalle	E-1a	(*f*)	33N	1E	14	SE	NW	Oglesby	6½
LaSalle	LaSalle	E-1c	(*f*)	33N	1E	14	SE	NW	Oglesby	6½
LaSalle	LaSalle	E-1d	(*f*)	33N	1E	14	SE	NW	Oglesby	5
LaSalle	LaSalle	E-6a	(*f*)	33N	1E	25		SE	LaSalle	
LaSalle	LaSalle	E-6b	(*f*)	33N	1E	25		SE	LaSalle	5
Livingston	Pontiac	P-2	(*g*)	28N	5E	16	SW	NE	Pontiac	11
Livingston	Pontiac	P-3	(*g*)	28N	5E	16	SW	NE	Pontiac	3
Livingston	Pontiac	P-4	(*g*)	28N	5E	16	SW	NE	Pontiac	1
Livingston	Pontiac	P-6	(*g*)	27N	4E	25	SE	NE	Ocoya	3
Livingston	Pontiac	P-8	(*g*)	27N	5E	1	NW	NE	McDowell	15
Logan	Shoal Creek?	E-28a	(*f*)	19N	3W	5	NW	NW	Lincoln	2
Logan	Shoal Creek?	E-28b	(*f*)	19N	3W	5	NW	NW	Lincoln	6
Macoupin	LaSalle	NF-100	(*e*)	10N	7W	36	NW	NW	Carlinville	7
Marshall	Lonsdale	E-20b	(*f*)	12N	9E	14	S½	NW	Sparland	5
Marshall	Lonsdale	E-23	(*f*)	12N	9E	14		SE	Sparland	2½
Montgomery	McLeansboro	DS-34	(*e*)	8N	5W	2	NW	NE	Litchfield	1½
Montgomery	LaSalle	698	(*f*)	8N	5W	2			Litchfield	20
Montgomery	LaSalle	L-425	(*c*)	8N	5W	2		SW	Litchfield	10
Peoria	Lonsdale	Bu-8	(*f*)	11N	7E	5		SE	Princeville	13½
Peoria	Lonsdale	Bu-9	(*f*)	8N	7E	10	SE	SE	Maxwell	9
Peoria	Lonsdale	E-24a	(*f*)	8N	7E	10		SE	Maxwell	3½
Peoria	Lonsdale	E-24b	(*f*)	8N	7E	10		SE	Maxwell	6½
Peoria	Lonsdale	E-24c	(*f*)	8N	7E	10	SE	SE	Maxwell	3
Perry	Caprock coal No. 6	DS-18	(*e*)	6S	2W	21	NE	SW	DuQuoin	15
Perry	Caprock coal No. 6	NF-77	(*e*)	6S	3W	11		NW	Pinckneyville	15
St. Clair	Caprock coal No. 6	NF-79	(*e*)	2S	7W	4		SE	Freeburg	5
St. Clair	Caprock coal No. 6	NF-80	(*e*)	2N	9W	24	NW	NE	French Village	4½
St. Clair	Caprock coal No. 6	NF-82, 83	(*e*)	2N	9W	26	SW	SE	French Village	5
St. Clair	Caprock Blair coal	NF-85	(*e*)	1N	9W	3	NW	NW	Centerville	4½
St. Clair	St. David	NF-84	(*e*)	1N	9W	3	NW	NW	Centerville	6
Schuyler	Seahorne	C-45	(*f*)	1N	1E	5	NW	NE	Frederick	8
Schuyler	Seahorne	C-46	(*f*)	2N	1E	32	NW	SW	Frederick	
Scott	Knobby	R-130	(*e*)	15N	13W	23	SE	SW	Exeter	3
Stark	Lonsdale	E-27a	(*f*)	14N	7E	21	SW	SE	Bradford	4
Stark	Lonsdale	E-27b	(*f*)	14N	7E	21	SW	SE	Bradford	5
Williamson	Caprock coal No. 6	NF-75	(*e*)	9S	2E	12	SE	NE	Spillertown	2
Williamson	Caprock coal No. 6	NF-76	(*e*)	8S	2E	32	SW	SE	Fordville	4

TABLE 12—*Typical analyses, Mississippian system, Chester series*—Continued

Shale

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O—	Loss on ignition 110°–400°C	Loss on ignition 400°–1000°C	Loss on ignition	Miscellaneous
-----	-----	3.66	2.82	55.46	16.20	5.28	-----	-----	-----	-----	-----	-----	-----	-----	-----	
-----	-----	1.52	2.29	63.44	18.30	6.39	-----	-----	-----	-----	-----	-----	-----	-----	5.94	SO_3–0.65
-----	-----	3.76	3.61	55.32	17.84	8.24	-----	-----	-----	-----	-----	-----	-----	-----	8.81	SO_3–1.88
25.09	4.21	*14.05*	*2.01*	46.54	17.85	0.43	-----	-----	-----	-----	-----	-----	-----	-----	-----	

PENNSYLVANIAN ("COAL MEASURES") SYSTEM

Limestone

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O—	Loss on ignition 110°–400°C	Loss on ignition 400°–1000°C	Loss on ignition	Miscellaneous
51.42	11.16	28.82	5.34	26.18	-----	-----	11.00	-----	-----	-----	-----	0.22	-----	-----	29.56	
57.3	*5.0*	32.1	2.4	26.4	4.8	2.7	-----	-----	-----	-----	-----	0.40	-----	-----	30.7	
60.42	6.19	33.86	2.96	23.30	-----	-----	8.64	-----	-----	-----	-----	0.46	-----	-----	32.38	
96.91	*1.32*	54.29	0.63	1.53	0.22	0.62	-----	-----	-----	-----	-----	-----	-----	-----	42.80	SO_3–0.05
91.46	1.38	51.26	0.66	4.04	-----	-----	2.94	-----	-----	-----	-----	0.17	-----	-----	41.92	
94.46	1.11	52.94	0.53	1.74	-----	-----	2.26	-----	-----	-----	-----	0.14	-----	-----	43.18	
95.00	1.44	53.24	0.69	2.12	-----	-----	1.56	-----	-----	-----	-----	0.08	-----	-----	43.16	
96.10	1.15	53.86	0.55	1.46	-----	-----	1.62	-----	-----	-----	-----	0.03	-----	-----	43.16	
82.11	4.10	46.02	1.96	6.26	-----	-----	5.50	-----	-----	-----	-----	0.22	-----	-----	40.78	
93.67	2.46	52.20	1.00	3.91	-----	-----	1.56	-----	-----	-----	-----	-----	-----	-----	-----	
92.62	2.97	51.90	1.42	2.66	-----	-----	2.34	-----	-----	-----	-----	0.22	-----	-----	42.00	
95.96	1.21	53.78	0.58	1.52	-----	-----	1.74	-----	-----	-----	-----	0.04	-----	-----	43.18	
82.61	2.82	46.30	1.35	8.02	-----	-----	5.52	-----	-----	-----	-----	0.25	-----	-----	38.98	
44.64	13.17	25.02	6.30	21.18	-----	-----	16.36	-----	-----	-----	-----	0.47	-----	-----	32.14	
90.14	1.86	50.52	0.89	4.92	-----	-----	3.08	-----	-----	-----	-----	0.17	-----	-----	41.08	
65.34	3.99	36.62	1.91	22.26	-----	-----	6.86	-----	-----	-----	-----	0.50	-----	-----	33.28	
65.38	5.06	36.64	2.42	17.76	-----	-----	9.56	-----	-----	-----	-----	0.57	-----	-----	34.36	
91.57	1.23	51.32	0.59	4.32	-----	-----	2.86	-----	-----	-----	-----	0.16	-----	-----	41.92	
82.22	1.55	46.08	0.74	9.62	-----	-----	5.56	-----	-----	-----	-----	0.38	-----	-----	39.16	
93.50	0.28	52.52	0.13	1.33	1.39	0.64	-----	-----	-----	-----	-----	-----	-----	-----	-----	
89.20	0.29	50.11	0.13	5.44	0.28	0.90	-----	-----	-----	-----	-----	-----	-----	-----	-----	
68.75	0.90	38.59	0.43	25.34	1.13	0.51	-----	-----	-----	-----	-----	-----	-----	-----	-----	
91.56	1.78	51.44	0.85	4.64	0.36	0.74	-----	-----	-----	-----	-----	-----	-----	-----	-----	
95.05	0.40	53.40	0.19	1.12	0.29	0.65	-----	-----	-----	-----	-----	-----	-----	-----	-----	
90.28	1.71	50.60	0.82	4.70	-----	-----	2.66	-----	-----	-----	-----	0.11	-----	-----	41.86	
83.79	8.95	46.96	4.28	2.04	-----	-----	4.92	-----	-----	-----	-----	0.16	-----	-----	42.84	
88.75	*3.12*	49.72	1.49	5.57	1.81	1.77	-----	-----	-----	-----	-----	0.26	-----	-----	40.16	
55.78	1.84	31.26	0.88	31.74	-----	-----	8.92	-----	-----	-----	-----	0.65	-----	-----	27.74	
92.36	1.50	51.76	0.72	3.42	-----	-----	2.36	-----	-----	-----	-----	0.22	-----	-----	41.38	
63.37	*9.89*	35.50	4.73	6.24	12.92	4.07	-----	-----	-----	-----	34.11	0.27	-----	-----	35.97	
93.53	2.15	52.42	1.03	2.06	-----	-----	3.45	-----	-----	-----	-----	0.16	-----	-----	42.26	
96.40	0.76	*53.98*	*0.36*	1.76	0.28	0.43	-----	-----	-----	-----	-----	-----	-----	-----	-----	FeS–0.30
83.40	0.88	46.74	0.42	13.36	-----	-----	3.24	-----	-----	-----	-----	0.14	-----	-----	37.94	
80.83	0.96	45.30	0.46	14.24	-----	-----	3.98	-----	-----	-----	-----	0.23	-----	-----	36.70	
70.05	1.00	39.26	0.48	21.96	-----	-----	5.88	-----	-----	-----	-----	0.48	-----	-----	32.88	
73.83	1.17	41.38	0.56	21.04	-----	-----	3.70	-----	-----	-----	-----	0.25	-----	-----	33.70	
91.93	3.89	51.52	1.86	2.78	-----	-----	1.82	-----	-----	-----	-----	0.12	-----	-----	42.70	
60.30	*7.30*	33.78	3.49	23.31	5.67	2.32	-----	-----	-----	-----	30.17	0.20	-----	-----	31.35	
54.1	*5.6*	30.3	2.7	29.1	7.49	2.21	-----	-----	-----	-----	-----	0.80	1.7	25.7	-----	MnO–0.07
57.8	*2.3*	32.4	1.1	28.5	6.18	2.92	-----	-----	-----	-----	-----	0.56	1.7	25.6	-----	MnO–0.14, Na_2O+K_2O as K_2O–1.2
83.0	*6.1*	46.5	2.9	7.0	-----	-----	4.8	-----	-----	-----	-----	0.13	0.0	38.9	-----	
30.0	*7.9*	16.8	3.8	47.3	-----	-----	13.0	-----	-----	-----	-----	0.78	1.0	16.6	-----	
60.2	*6.5*	33.7	3.1	23.6	5.13	3.87	-----	-----	-----	-----	-----	0.54	0.6	29.6	-----	
81.0	*1.3*	45.4	0.6	15.3	-----	-----	3.1	-----	-----	-----	-----	0.04	0.2	35.9	-----	
95.32	0.92	53.42	0.44	2.66	-----	-----	2.18	-----	-----	-----	-----	0.14	-----	-----	42 48	
94.78	0.92	53.12	0.44	3.10	-----	-----	2.14	-----	-----	-----	-----	0.24	-----	-----	42 22	
95.48	*0.63*	53.49	0.30	0.47	1.36	1.05	-----	0.00	0.00	0.00	42.05	0.00	-----	-----	42.50	S–0.35
62.95	2.05	35.28	0.98	27.24	-----	-----	7.58	-----	-----	-----	-----	0.78	-----	-----	29.66	
79.44	1.50	44.52	0.72	15.40	-----	-----	2.80	-----	-----	-----	-----	0.29	-----	-----	36.38	
54.8	*26.8*	30.7	12.8	9.0	-----	-----	8.8	-----	-----	-----	-----	0.00	0.6	38.3	-----	
76.8	*12.1*	43.0	5.8	7.7	-----	-----	3.9	-----	-----	-----	-----	0.00	0.4	39.4	-----	

Table 12—*Typical analyses, Pennsylvanian system*—Continued

County	Formation	Sample No.	Reference	Location						Thickness sampled (feet)
				T	R	Sec.	¼	¼	Near	
Shale and Clay										
Bureau	LaSalle	E-15b	(*i*)	16N	11E	31			Marquette	7
Calhoun	Shale above Golden Eagle coal	R-11	(*d*)	14S	2W	1	SE	NW	Golden Eagle	30
Calhoun	Pottsville		(*j*)	8S	3W	6		SW	Belleview	5
Calhoun	Pottsville		(*j*)	8S	3W	6		SW	Belleview	4
Calhoun	Pottsville		(*j*)	8S	3W	6		SW	Belleview	3±
Clark	McLeansboro	L-14	(*i*)	11N	12W	12		NE	Marshall	8
Clark	McLeansboro	L-15	(*i*)	11N	12W				Marshall	5
Edgar	McLeansboro	L-12	(*i*)						Baldwinsville	20
Edgar	McLeansboro	L-13	(*i*)						Baldwinsville	6
Edwards	McLeansboro	K-3	(*h*)	2S	10E	12		N½	Albion	
Fulton	Canton	R-215	(*e*)	5N	5E	7	SE	NW	Canton	8
Fulton	Purington	R-214	(*e*)	6N	5E	31	SW	SE	Canton	13
Greene	Pottsville	F-6	(*k*)	12N	11W	30		SW	Whitehall	6
Greene	Pottsville	F-16	(*k*)	12N	11W	30		SW	Whitehall	17
Greene	Pottsville	F-18	(*k*)	12N	12W	30		NE?	Drake	5
Greene	Pottsville	F-19	(*k*)	12N	12W	30		NE?	Drake	5
Knox	Purington	K-6	(*h*)	11N	2E	17		SW	Galesburg	
LaSalle	LaSalle	E-1b	(*i*)	33N	1E	14	SE	NW	LaSalle	3½
LaSalle	Shale below LaSalle limestone	E-6e	(*i*)	33N	1E	25		SE	Oglesby	5½
LaSalle	Shale over Streator coal	K-7	(*h*)						Streator	
LaSalle	Pottsville	V-4	(*k*)	33N	2E	20		NE	Utica	12
LaSalle	Pottsville	V-11	(*k*)	33N	3E	12		SE	Ottawa	
LaSalle	Francis Creek	W-79	(*e*)	33N	3E	18	NE	NE	Ottawa	12
LaSalle	Shale over LaSalle limestone	W-7	(*e*)	33N	1E	14	SE	NW	LaSalle	8
Livingston	Shale over Streator coal	K-15	(*h*)	30N	3E	12	NW	NE	Streator	
McDonough	Pottsville	H-45	(*k*)						Macomb	5
McDonough	Pottsville	H-46	(*k*)						Macomb	5
Madison	Francis Creek?	K-1	(*h*)						Alton	
Madison	McLeansboro	K-5	(*h*)						Edwardsville	
Marshall	Shale, over coal No. 7	W-43	(*e*)	12N	9E	27	NW	NE	Sparland	15
Montgomery	McLeansboro	L-8	(*i*)	8N	5W	2			Quarry	7
Rock Island	Pottsville	H-23	(*h*)	18N	1E	5?			Carbon Cliff	
Rock Island	Pottsville	H-10	(*k*)	18N	1E	5	NE	SE	Carbon Cliff	
Sangamon	McLeansboro	K-4	(*h*)	15N	5W	1	SW	SW	Springfield	
Schuyler	Francis Creek	L-7a	(*i*)	1N	1E	8		SW	Frederick	8
Schuyler	Pottsville	L-7b	(*i*)	1N	1E	8		SW	Frederick	10
Stark	McLeansboro	L-1	(*i*)	12N	7E	32		NE	Wady Petra	4
Tazewell	Carbondale	H-16	(*h*)	25N	4W	6		NE	E. Peoria	
Vermilion	McLeansboro	K-14	(*h*)	19N	12W	12		SW	Danville	
Vermilion	McLeansboro	F-1	(*h*)	19N	11W	7	NW	SE	Danville	
Wabash	McLeansboro	L-16	(*i*)	1S	13W	36			Mt. Carmel	

TABLE 12—*Typical analyses, Pennsylvanian system*—Continued

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O—	Loss on ignition 110°-400°C	Loss on ignition 400°-1000°C	Loss on ignition	Miscellaneous
Shale and Clay																
----	----	7.94	2.74	49.10	----	----	27.34	----	----	----	----	----	----	----	12.88	
----	----	1.05	2.04	58.04	24.40	6.66	----	----	----	----	----	----	----	----	7.61	SO_3-0.86
----	----	Trace	0.84	52.00	33.39	2.21	----	----	----	----	----	----	----	----	11.52	Fireclay
----	----	Trace	0.30	57.24	30.74	1.74	----	----	----	----	----	----	----	----	10.03	Fireclay
----	----	0.71	0.07	45.17	38.78	1.78	----	----	----	----	----	----	----	----	13.16	SO_3-0.33; flint clay
----	----	2.01	3.38	66.32	17.25	7.44	----	----	----	----	----	----	----	----	3.32	
----	----	1.57	3.46	68.20	14.09	9.94	----	----	----	----	----	----	----	----	2.42	
----	----	1.56	3.52	58.90	19.09	8.11	----	----	----	----	----	----	----	----	6.18	
----	----	1.58	1.86	74.24	13.58	5.73	----	----	----	----	----	----	----	----	2.02	
----	----	0.76	1.82	59.34	15.36	3.26	----	1.31	0.80	3.82	----	0.29	----	----	7.89	FeO-3.84, S-0.16
----	----	0.65	1.69	68.25	15.36	4.52	----	1.19	1.41	2.49	0.37	0.22	----	----	4.56	S-0.10
----	----	0.69	1.64	63.59	18.02	5.60	----	1.21	0.97	2.77	1.17	0.43	----	----	5.65	S-0.18
----	----	----	----	67.37	21.69	1.59	----	1.32	----	----	----	1.38	----	----	6.17	Fireclay
----	----	----	----	61.34	25.76	2.14	----	1.22	----	----	----	1.46	----	----	6.88	Fireclay
----	----	----	----	66.88	21.87	2.23	----	1.18	----	----	----	0.84	----	----	6.66	Fireclay
----	----	----	----	68.12	20.08	1.76	----	1.16	----	----	----	1.19	----	----	6.31	Fireclay
----	----	0.63	1.44	63.62	16.28	3.02	----	0.96	1.50	2.60	----	0.38	----	----	5.88	FeO-2.90, S-0.11
----	----	13.82	2.10	49.02	----	----	20.14	----	----	----	----	----	----	----	15.46	
----	----	7.64	1.78	53.48	----	----	22.36	----	----	----	----	----	----	----	14.66	
----	----	1.05	2.32	59.86	17.43	1.42	----	1.61	0.18	2.80	----	0.20	----	----	6.35	FeO-5.10, S-0.13
----	----	----	----	54.80	29.44	1.70	----	0.82	----	----	----	2.37	----	----	8.84	Fireclay
----	----	----	----	56.28	26.68	3.24	----	1.28	----	----	----	1.74	----	----	10.28	Fireclay
----	----	0.31	1.77	55.64	23.67	4.70	----	1.00	0.44	4.66	0.07	0.69	----	----	7.10	S-0.68
----	----	2.32	2.13	56.40	18.97	8.86	----	0.92	0.85	3.21	1.06	0.35	----	----	6.90	S-0.00
----	----	1.42	1.43	58.03	17.72	2.91	----	1.02	1.40	2.66	----	0.97	----	----	6.47	FeO-5.77, S-0.25
----	----	----	----	83.34	8.42	0.80	----	0.80	----	----	----	0.49	----	----	3.03	Fireclay
----	----	----	----	77.88	14.42	1.05	----	0.93	----	----	----	0.81	----	----	4.32	Fireclay
----	----	0.93	1.58	63.36	15.43	1.80	----	1.00	0.56	3.28	----	0.48	----	----	6.99	FeO-4.02, S-0.27
----	----	1.00	2.11	63.43	16.89	1.52	----	1.07	0.20	2.03	----	0.46	----	----	5.97	FeO-4.24, S-0.11
----	----	1.64	0.90	46.73	20.88	10.86	----	0.85	----	----	0.37	0.92	----	----	10.98	
----	----	1.51	1.60	71.65	12.69	6.32	----	----	----	----	----	----	----	----	5.10	
----	----	1.76	0.65	55.37	21.40	6.72	----	----	----	----	----	3.39	----	----	8.75	Na_2O+K_2O-2.41
----	----	----	----	76.10	15.31	1.10	----	1.31	----	----	----	0.60	----	----	4.63	Fireclay
----	----	0.41	1.96	60.31	17.74	5.04	----	0.84	1.07	2.88	----	0.81	----	----	6.71	FeO-1.96, S-0.14
----	----	0.63	2.09	73.78	16.20	1.76	----	----	----	----	----	----	----	----	4.63	
----	----	0.63	2.10	73.66	16.37	2.06	----	----	----	----	----	----	----	----	4.85	
----	----	1.61	3.21	57.67	21.60	6.63	----	----	----	----	----	----	----	----	6.80	
----	----	1.33	0.91	60.93	17.93	8.12	----	----	----	----	----	0.55	----	----	5.73	K_2O+Na_2O-5.01
----	----	1.69	1.64	64.09	14.16	2.65	----	0.89	0.77	2.90	----	0.51	----	----	6.47	FeO-3.16, S-0.24
----	----	1.05	1.45	58.52	15.67	4.99	----	0.96	1.48	2.94	----	2.02	----	----	7.72	FeO-3.37, S-0.32
----	----	2.31	3.06	55.95	18.89	8.09	----	----	----	----	----	----	----	----	8.74	

TABLE 12—*Typical analyses*—Concluded

CRETACEOUS–TERTIARY SYSTEMS

County	Formation	Sample No.	Reference	Location. T	R	Sec.	¼	¼	Near	Thickness sampled (feet)
Clay										
Massac	Ripley	D-28	(*k*)	15S	4E	1		SW	Round Knob	6
Massac	Ripley	D-29	(*k*)	15S	4E	2	N½	SW	Round Knob	
Massac	Ripley	D-30	(*k*)	15S	4E	2	N½	SW	Round Knob	6
Massac	Ripley	D-31	(*k*)	15S	4E	2	N½	SW	Round Knob	6½
Massac	Ripley	D-32	(*k*)	14S	5E	33		SE	Rosebud	4
Massac	Ripley	D-50	(*k*)	16S	6E	12			Hamletsburg	4
Pulaski	Lagrange	D-44	(*k*)	15S	1W	31			Unity	10
Pulaski	Lagrange	D-45	(*k*)	15S	1W	15			Pulaski	
Pulaski	Lagrange	D-46	(*k*)	15S	1W	15			Pulaski	3
Pulaski	Porters Creek	G-116	(*e*)	15S	1E	27	NE	SE	Olmstead	10
Pulaski	Porters Creek	La-3	(*e*)	15S	1E	26	NW	NW	Olmstead	15
Pulaski	Ripley	D-33	(*k*)	15S	2E	1			Yates Landing	8
Pulaski	Ripley	D-36	(*k*)	15S	2E	18			Dam 53	
Union	Lagrange	D-10	(*k*)	11S	2W	35	SE	SW	Kaolin	
Union	Lagrange	D-11	(*k*)	11S	2W	35	SE	SW	Kaolin	
Union	Lagrange	D-12	(*k*)	11S	2W	35	SE	SW	Kaolin	
Union	Lagrange	D-13	(*k*)	11S	2W	35	SE	SW	Kaolin	
Union	Lagrange	D-14	(*k*)	11S	2W	35	SE	SW	Kaolin	

PLEISTOCENE SYSTEM

Clays, Silts and Sands

Alexander	Loess	DS-4	(*e*)	15S	3W	4	SE	NW	Gale	48
Brown	Illinoian outwash	L-6	(*i*)	2S	2W	19			Versailles	
Cook	Wisconsin silt	D-5	(*e*)	37N	14E	35		SW	Dolton	7
Cook	Wisconsin till	D-7	(*e*)	39N	14E	33	SE	SE	Cicero	17
Cook	Wisconsin till	DS-82	(*e*)	37N	14E	30	SE	NE	Blue Island	25
Cook	Wisconsin till	NF-57	(*e*)	36N	14E	33	NW	SE	Thornton	6
Ford	Cropsey till	DS-101	(*e*)	23N	10E	17	NW	NW	Paxton	23
Grundy	Dune sand	W-721	(*e*)	33N	8E	24	SE	NE	Coal City	10
Grundy	Marseilles till	DS-91	(*e*)	33N	6E	30	NE	SE	Seneca	25
Hancock	Loess	L-3	(*i*)						Niota	
LaSalle	Wisconsin clay	W-13	(*e*)	34N	4E	9	SE	NW	Wedron	12
Lee	Wisconsin till	DS-71D	(*e*)	22N	9E	27	SE	NW	Dixon	30
Mason	Dune sand	R-300	(*e*)	20N	9W	11	SE	SW	Bath	
Peoria	Loess	R-216	(*e*)	8N	9E	26	SE	NE	Bartonville	9
Randolph	Loess	L-9	(*i*)	5S	9W	20			Prairie du Rocher	
Randolph	Loess	S-4	(*d*)	7S	7W	23	NW	NE	Menard	20
Union	Loess	L-10	(*i*)	12S	1W	20	NW	NE	Anna	8

(a) Includes published analyses, analyses of samples taken during rock wool studies, and analyses made during other studies but unpublished.

Figures not reported in original analyses but calculated are shown in *italics*.

Calculations have been made by using direct factoral multiplication or division in keeping with the practices commonly employed commercially. The calculations were made as follows:

$CaCO_3 = CaO \times 1.785$ $\quad$ $CaO = CaCO_3 \times 0.560$

$MgCO_3 = MgO \times 2.091$ $\quad$ $MgO = MgCO_3 \times 0.478$

(b) Analyses for Illinois State Geological Survey by Chemistry Department of the University of Illinois.

(c) Illinois State Geol. Survey Bull. 46, 1925, p. 311.

(d) Analyses for Illinois State Geological Survey by Illinois Division of Highways.

(e) Analyses made by the Analytical Division of the State Geological Survey by C. S. Westerberg and L. D. McVickers under the direction of Dr. O. W. Rees.

(f) Illinois State Geol. Survey Bull. 17, 1912, p. 97.

(g) Illinois State Geol. Survey Report of Investigations No. 17, 1929, p. 13.

(h) Illinois State Geol. Survey Bull. 9, 1908, p. 215.

(i) Illinois State Geol. Survey Bull. 17, 1912, p. 104.

(j) Illinois State Geol. Survey Report of Investigations No. 22, 1931, p. 22.

(k) Illinois State Geol. Survey Bull. 4, 1907, pp. 150-159, 161, 164, 166-169, 178.

Table 12—*Typical analyses*—Concluded

CRETACEOUS–TERTIARY SYSTEMS

Clay

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O—	Loss on ignition 110°-400°C	Loss on ignition 400°-1000°C	Loss on ignition	Miscellaneous
-----	-----	-----	-----	66.04	22.00	1.60	-----	1.60	-----	-----	-----	1.64	-----	-----	6.81	
-----	-----	-----	-----	71.58	18.31	1.51	-----	1.40	-----	-----	-----	1.41	-----	-----	5.27	
-----	-----	-----	-----	60.50	22.52	3.84	-----	1.40	-----	-----	-----	3.44	-----	-----	7.52	
-----	-----	-----	-----	69.46	18.82	1.32	-----	1.64	-----	-----	-----	1.13	-----	-----	5.31	
-----	-----	-----	-----	64.88	21.54	1.86	-----	1.26	-----	-----	-----	2.58	-----	-----	6.83	
-----	-----	-----	-----	63.32	19.25	4.09	-----	0.48	-----	-----	-----	3.55	-----	-----	6.02	
-----	-----	-----	-----	69.92	20.19	1.21	-----	0.98	-----	-----	-----	1.11	-----	-----	6.35	
-----	-----	-----	-----	62.76	22.36	3.07	-----	0.97	-----	-----	-----	2.99	-----	-----	6.12	
-----	-----	-----	-----	57.14	25.52	2.82	-----	1.08	-----	-----	-----	3.48	-----	-----	8.12	
-----	-----	0.86	2.00	61.06	15.99	4.50	-----	0.21	0.07	1.43	-----	5.88	-----	-----	13.36	FeO-0.12, P_2O_5-0.36
-----	-----	0.85	1.79	69.07	11.87	4.36	-----	0.84	0.00	1.40	0.03	4.52	-----	-----	10.21	S-0.00
-----	-----	-----	-----	67.54	21.54	1.70	-----	0.78	-----	-----	-----	2.48	-----	-----	6.29	
-----	-----	-----	-----	68.26	20.87	2.03	-----	1.14	-----	-----	-----	1.90	-----	-----	5.56	
-----	-----	-----	-----	43.90	40.79	1.76	-----	2.40	-----	-----	-----	1.25	-----	-----	9.90	
-----	-----	-----	-----	48.30	31.14	1.02	-----	3.20	-----	-----	-----	0.97	-----	-----	15.37	
-----	-----	-----	-----	56.55	29.97	1.23	-----	2.75	-----	-----	-----	0.86	-----	-----	8.64	
-----	-----	-----	-----	47.95	37.86	1.23	-----	3.01	-----	-----	-----	0.90	-----	-----	9.05	
-----	-----	-----	-----	52.65	33.98	0.97	-----	2.92	-----	-----	-----	0.87	-----	-----	10.61	

PLEISTOCENE SYSTEM

Clays, Silts and Sands

$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	TiO_2	Na_2O	K_2O	CO_2	H_2O—	Loss on ignition 110°-400°C	Loss on ignition 400°-1000°C	Loss on ignition	Miscellaneous
-----	-----	5.17	5.11	63.96	13.76	3.27	-----	-----	-----	-----	5.52	1.10	-----	-----	8.82	
-----	-----	5.55	3.34	61.11	14.76	6.31	-----	-----	-----	-----	-----	-----	-----	-----	8.00	
-----	-----	10.47	5.27	48.64	12.20	4.19	-----	-----	0.69	3.25	-----	0.35	-----	-----	15.67	S-0.16
-----	-----	8.13	5.04	50.35	12.92	4.96	-----	-----	0.56	3.57	-----	0.32	-----	-----	13.79	S-0.62
-----	-----	7.82	5.01	52.01	17.04	4.56	-----	-----	-----	-----	9.51	0.68	-----	-----	13.70	
-----	-----	10.1	6.4	48.4	-----	-----	17.5	-----	-----	-----	-----	0.42	3.0	12.3	-----	Na_2O+K_2O as K_2O-4.0
-----	-----	7.35	5.92	51.03	12.95	4.90	-----	-----	-----	-----	9.54	1.05	-----	-----	13.56	
-----	-----	0.94	0.46	88.04	5.46	1.75	-----	0.28	0.76	1.54	0.00	0.05	-----	-----	0.63	S-0.00
-----	-----	9.43	6.50	49.58	13.25	4.45	-----	-----	-----	-----	12.69	0.48	-----	-----	16.75	
-----	-----	1.80	1.58	76.00	9.68	5.76	-----	-----	-----	-----	-----	-----	-----	-----	3.62	
-----	-----	13.69	5.11	40.36	11.80	3.60	-----	0.58	0.54	2.93	16.45	2.09	-----	-----	21.48	S-Trace
-----	-----	12.06	6.60	45.91	13.62	4.03	-----	-----	-----	-----	13.98	0.90	-----	-----	16.96	
-----	-----	0.95	0.21	92.28	3.84	0.73	-----	0.00	0.20	1.18	0.07	0.00	-----	-----	0.68	S-0.00
-----	-----	6.98	4.46	61.70	9.16	3.10	-----	0.12	1.13	2.18	8.62	0.80	-----	-----	11.46	S-0.04
-----	-----	2.01	2.04	75.93	11.96	3.48	-----	-----	-----	-----	-----	-----	-----	-----	3.20	
-----	-----	1.85	1.22	72.13	12.02	4.05	-----	-----	-----	-----	-----	-----	-----	-----	6.05	SO_3-0.19
-----	-----	2.12	2.18	73.10	13.45	5.33	-----	-----	-----	-----	-----	-----	-----	-----	2.86	

Part III

CHEMICAL INVESTIGATIONS

By Charles F. Fryling, Ph.D.

Under the supervision of

Frank H. Reed, Ph.D., *Chief Chemist*

CHAPTER VI—EXPERIMENTAL PRODUCTION OF ROCK WOOL FROM ILLINOIS MINERAL DEPOSITS

INTRODUCTION

Rock wool is a heat and sound insulating material manufactured from impure limestone. It is soft, generally white in color, and consists of a tangled mass of thin glass fibers interspersed with small glass beads or "shot". In its manufacture, rocks or rock mixtures of suitable composition are melted in cupolas using coke as a fuel. The molten material is allowed to flow in a steady stream into a blast of air or steam. It is thereby disintegrated into a mass of fluffy material and is propelled into a suitable collecting chamber. Before it appears on the market, it may be further subjected to various refining and fabricating processes.

The investigation has included a study of (1) the mineral deposits within the State which are potentially suitable for rock wool production; (2) the possibility of producing rock wool by mixing materials from deposits which occur in close proximity to each other; and (3) the characteristics of the wools produced from various deposits.

Two methods were employed in determining what materials are suitable for the manufacture of rock wool, namely, chemical analysis, and a small scale blowing test with operating conditions similar to those employed in the manufacture of rock wool.

The use of chemical analysis alone presupposes information correlating composition with rock wool production, and heretofore this information has been meager. The blowing test, carried out without regard to chemical analysis, is purely empirical; information thus obtained is not applicable to the evaluation of other deposits. In this inquiry, the advantages of both procedures were combined, i.e., all materials subjected to blowing tests were also analyzed.

EXPERIMENTAL TESTING OF SAMPLES FROM ILLINOIS MINERAL DEPOSITS

The Illinois materials tested were carefully selected from a large number of representative samples collected from various parts of the State. Because the subjection of all possible samples either to an analysis or a blowing test would be an almost endless task, a rapid test for eliminating unlikely materials was necessary. The carbon dioxide content of a rock sample was found to be a valuable index (Appendix II). The validity of the test was established by comparison with experimentally determined limits of compositions useful for rock wool production.

One kilogram of calcined woolrock was melted in an electrically heated graphite crucible and held at 1500°C. for 15 minutes. The temperature was then adjusted to the pouring temperature desired and the molten material was poured into the steam blast (Appendix III).

Certain differences between the experimental method and the procedure used for commercial production of wool are:

1) There is a large difference in the scale on which the operations are conducted;

2) The atmosphere in contact with the molten small scale samples is more highly reducing;

3) A steady state cannot be obtained during the pouring of the experimental charge—the blast must be quickly adjusted and held constant for a short time;

4) The experimental blast pressure is lower than that used commercially;

5) No attempt is made to oil the wool during the experimental blowing. However, the close similarity of results indicates that these differences are of minor significance for the purpose of testing the suitability of samples from various deposits.

Samples which yielded satisfactory rock wools are described briefly in Table 13 and more fully in the geological section of the report. Identification of the samples in the geological descriptions may be made through the sample numbers.

Table 14 gives the chemical composition of the rock wool obtained by experimental tests and information on the pouring time, blast pressure, pouring temperature, the average diameter of the fibers, the average diameter of the shot, and the color of the wool.

The average fiber diameter and the average shot diameter are characteristic criteria of the quality of the rock wool because these contribute to the low heat conductivity, softness, gross density, and appearance. These diameters are reported in microns (one micron is equal to 0.001 millimeter or 39.37 millionths of an inch) and were determined with a microscope. The values reported are the average of about a hundred measurements of individual fiber diameters made on small samples taken at random from each of the wools. The measurement of average diameters is more dependable for fibers than for shot since the larger shot tend to fall out of the samples.

The pouring time was varied intentionally in only the first three experiments; further variation in this quantity is a consequence of the variation of viscosity of the various samples with temperature and composition.

The influence of pouring temperature was determined for a number of rock samples (Chapter VII).

TABLE 13—*Bedrock deposits from which rock wool was produced experimentally*

Sample No.	Character of deposit	Thickness (Feet)	Rock composition						
			SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Ignition loss	Misc.
NF-59a	Dolomite	?	28.86	7.39	2.14	13.60	17.15	28.20	2.86
NF-60	Dolomite	?	31.2	9.2	2.0	12.9	17.7	27.1	....
NF-29	Calcareous shale	7½	29.7	6.9	1.5	13.5	19.1	28.9	0.4
NF-77	Caprock, coal No. 6	15	29.1	7.5	2.2	2.7	30.3	27.4	0.8
NF-56	Dolomitic shale	1	33.4	9.0	2.0	12.3	16.6	26.2	0.5
NF-70	Cherty limestone	60	36.3	2.2	1.4	2.9	31.5	26.7	....
DX-17A	Interbedded limestone and shale	....	29.07	5.13	3.34	3.30	29.79	29.41	....
NF-73	Cap limestone, coal No. 6	15	26.9	4.9	2.1	2.1	34.0	29.8	1.4
NF-85	Caprock, coal No. 5	4½	23.6	5.1	3.9	3.1	33.7	30.2	0.4
NF-79	Caprock, coal No. 6	5	28.5	6.2	2.9	1.1	32.4	27.3	1.6
NF-46	Interbedded shale and limestone	6½	29.4	10.6	2.9	11.6	16.6	25.8	3.2
NF-83	Caprock, coal No. 6	1½	27.9	4.1	4.4	7.3	27.6	27.8	0.9
DS-74	Interbedded shale and limestone	35	29.66	13.14		11.61	17.43	28.32	....
DX-5	Cherty dolomite	10	41.08	2.01	1.88	11.95	17.49	25.91	....
NF-91	Cherty limestone	45	37.25	3.21	1.12	2.30	30.37	25.48	0.27
NF-92	Cherty limestone	50	41.44	3.93	1.10	2.82	26.82	23.47	0.42
NF-93	Cherty limestone	30	31.53	2.96	1.07	1.65	34.55	27.99	0.25
NF-94	Cherty limestone	100	31.81	2.64	1.74	2.90	33.21	28.35	....
NF-96	Dolomite	?	26.95	6.45	1.36	13.60	19.62	30.28	2.32
NF-89	Siliceous limestone	11	40.2	2.4		0.8	31.4	24.6	0.6
NF-99	Shale	15	29.76	7.95	2.82	12.21	17.74	27.15	2.37
NF-125	Shale	2	34.37	8.56	2.30	11.53	18.24	24.92	0.08

TABLE 14—*Data obtained from the experimental production of rock wool from Illinois bedrock deposits*

Experiment No.	Sample No.	Composition					Pouring time (seconds)	Blast pressure (lb. per sq. in.)	Pouring temperature °C	Average fiber diameter (microns)	Average shot diameter (microns)	Color
		SiO_2	R_2O_3	MgO	CaO	Misc.						
1	NF-59a	40.4	13.2	19.0	24.0	3.5	33	75	1508	3	48	White
2							19	75	1503	4	52	White
3							11.5	75	1504	4	52	White
4	NF-60	42.8	15.2	17.7	24.3	......	35	80	1494	4	55	White
5							36	80	1558	4	55	White
6							36	80	1449	6	50	White
7							40	80	1400	6	58	White
8							40	80	1270	13	82	White
9							36	40	1441	6	57	White
10							38	40	1504	4	41	White
11							37	40	1396	8	60	White
12	NF-29	41.8	11.8	19.0	26.9	0.6	34	80	1502	4	58	White
13							35	80	1406	5	60	White
14							38	80	1300	8	90	Light gray
15							32	80	1440	4	60	White
16							34	40	1443	4	46	White
17							37	20	1450	6	60	White
19	NF-77	40.1	13.4	3.7	41.7	1.1	33	57	1504	4	62	Light tan
20							40	60	1297	14	....	Brown
21							37	60	1398	6	90	Tan
22							35	80	1449	4	46	Tan

23	NF-56	45.3	14.9	16.7	22.5	0.7	39	77	1504	5	68	Light tan
24							37	70	1398	10	130	Light tan
25							40	70	1295	14	......	Light tan
27	NF-70	48.9	4.8	3.9	42.4	......	30	70	1486	3	47	White
28							56	70	1395	5	68	White
30	DX-17A	41.1	12.0	4.7	42.2	......	30	70	1459	3	32	White
31							29	70	1420	5	60	White
34	NF-73	37.7	9.8	2.9	47.6	2.0	32	70	1494	3	36	White
35							30	70	1412	6	60	White
39	NF-85	33.8	12.9	4.4	48.3	0.6	29	70	1464	3	45	White
40	NF-79	39.2	12.5	1.5	44.6	2.2	31	70	1506	3	35	Light tan
41							32	70	1412	5	50	Light tan
42							35	70	1305	9	115	Tan
43	NF-46	39.6	18.2	15.6	22.3	4.3	38	70	1498	4	43	White
44							(*a*)	70	1394	7	60	White
45							35	70	1346	8	170	White
46	NF-83	38.6	11.8	10.1	38.2	1.2	32	70	1498	4	16	Dark brown
47							32	70	1396	3	37	Dark brown
65	DS-74	41.4	18.3	16.2	24.3	......	(*a*)	70	1492	5	37	White
66	DX-5	55.3	5.2	16.1	23.5	......	(*a*)	70	1490	5	70	White
71	NF-91	50.1	5.8	3.1	40.7	0.4	(*a*)	70	1496	3	37	White
72	NF-92	54.1	6.6	3.7	35.1	0.5	(*a*)	40	1431	4	40	White
73	NF-93	43.8	5.6	2.3	48.0	0.3	(*a*)	70	1503	4	26	White

TABLE 14—Concluded

Experiment No.	Sample No.	Composition					Pouring time (seconds)	Blast pressure (lb. per sq. in.)	Pouring temperature °C	Average fiber diameter (microns)	Average shot diameter (microns)	Color
		SiO_2	R_2O_3	MgO	CaO	Misc.						
74	NF-94	44.0	6.1	4.0	46.0	......	(a)	70	1500	4	34	White
75	NF-92	54.1	6.6	3.7	35.1	0.5	(a)	70	1446	4	29	White
78	NF-96	38.4	11.1	19.3	27.9	3.3	(a)	70	1488	4	29	White
123	NF-89	53.3	3.2	1.1	41.6	0.8	(a)	70	1500	6	....	White
196	NF-99	40.8	14.8	16.8	24.3	3.3	(a)	70	1500	3	....	White
197	NF-125	45.7	14.5	15.3	24.3	0.1	(a)	70	1500	6	....	White

(a) Pouring time not measured. The rate of tilting the crucible was the same in all cases, so that the pouring times were between 30 and 38 seconds, depending upon the viscosity of the melts.

REMARKS ON SAMPLES OF ILLINOIS MATERIALS WHICH YIELDED EXPERIMENTAL WOOLS

NF-59a, NF-60, NF-96: These samples, obtained from the spoil bank along Sag Channel near Blue Island, furnished an excellent quality of rock wool. The products are soft and exhibit good color. The rock can be blown at temperatures from 1400°C. to 1550°C. It is believed that these samples came from various parts of the same deposit. Core drillings are discussed in the geological section (pp. 65-83).

NF-29: This sample, from a 7½-foot deposit of calcareous shale, yielded a satisfactory white rock wool. The composition of this product is very close to the compositions of certain rock wools which are being produced commercially (p. 93).

NF-77: The deposit from which this sample was taken is 15 feet thick, which assures an adequate supply of raw material. The wool is light brown in color and is not unattractive although white wool is in demand. It has been suggested that the brown color might be used as a means of identifying the brand. It is believed that semi-plant scale development may reveal a means of producing a white product by removing the sulfur compounds which are probably responsible for the color (p. 23).

NF-56: The color of the wool produced from this sample is not good and the deposit appears to be too thin (1 foot) to warrant consideration. Except for color, the quality of the wool is good.

NF-70, NF-91, NF-92, NF-93, NF-94: These samples, taken from various parts of an extensive deposit, were the most promising materials examined. Although their composition differs markedly from that of most wool-rocks in that they all exhibit low alumina and high silica content, each yielded a satisfactory product. The wool is soft and resembles cotton batting.

The supply of raw material, from which these samples were obtained, is apparently inexhaustable. The deposit is located close to sources of fuel and to the St. Louis market. The Bailey formation, from which these samples were taken, consists of limestone including nodules and beds of chert. The chert disintegrates sometimes when subjected to high temperature but just what conditions will have to be maintained to secure a rapid reaction between the chert and the limestone within the cupola remains to be determined by semi-plant scale operations (pp. 33-35).

DX-17A: This sample from a deposit of interbedded limestone and shale produced a wool which was not entirely satisfactory. The color was good, but the wool was extremely soft and tended to pack together and be heavy. Analysis shows that it falls barely within the limits of composition suitable for rock wool production (Chapter VII). The addition of small quantities of sandstone or shale, probably not more than 160 pounds per ton of *DX-17A* would improve the quality considerably. The fact that small additions of siliceous rock would be required with *DX-17A* should not be considered detrimental (p. 52).

NF-73: The composition of this sample taken from a 15-foot deposit is very similar to that of sample *DX-17B.* To secure best results, it would seem necessary to add a moderate quantity of shale or sandstone (about 150 pounds per ton). The color of the wool is good and the character of the deposit justifies its consideration for rock wool production (p. 24).

NF-85: This sample from a 4½-foot deposit lies just within the composition limits of woolrock. The production of a good wool from this sample would require the addition of shale or sandstone to the extent of about 200 pounds per ton of sample. The color of the wool is good (p. 85).

NF-79: This sample from a 5-foot deposit yields a light brown wool (see *NF-77*). Like *DX-17A* it should also be mixed with about 150 pounds of shale or sandstone per ton of *NF-79* (p. 30).

NF-46: This sample from a 6½-foot deposit produced a satisfactory white rock wool (p. 90).

NF-83: This sample from a 1½-foot deposit yields a dark brown wool (p. 85).

DS-74: This sample, obtained from a 35-foot outcrop of interbedded shale and limestone, produced an excellent wool. The experimental evidence indicates that this deposit is worthy of consideration as a source of raw material for rock wool production. It is possible, however, that considerable care may be necessary in quarrying to produce the rock in a physical condition suited to the cupolas (p. 40).

DX-5: This sample produced a satisfactory product, very soft, and resmbling cotton batting. Ten feet of *DX-5* overlies 15 feet of *DX-4,* a cherty dolomite with the following composition:

	Per cent
SiO_2	24.8
Al_2O_3	1.1
Fe_2O_3	1.9
MgO	15.0
CaO	23.0
CO_2	34.3

This rock is too low in acidic constituents, silica and alumina, to yield a rock wool. A mixture of *DX-5* with *DX-4* in the ratio of the thickness of their respective formations (10:15), produced a satisfactory rock wool with the calculated composition:

	Per cent
SiO_2	45
R_2O_3	5
MgO	20
CaO	30

Any mixture from *DX-5* alone to *10 DX-5:15 DX-4* would be satisfactory as regards composition. That mixture which could be most readily accommodated by the cupolas, with due regard to the characteristics of the product, should be used. This location appears to offer a promising possibility for commercial development (p. 97).

NF-89: This sample, obtained from an 11-foot outcrop of siliceous limestone, produced a satisfactory white rock wool (p. 102).

NF-99: This sample, obtained from a 15-foot outcrop of wool rock, produced an excellent rock wool (p. 44).

NF-125: This sample from a 2-foot deposit produced a satisfactory wool (p. 99).

EXPERIMENTAL DUPLICATION OF COMMERCIAL PRODUCTS

The validity of deductions based on blowing tests rests in part on the closeness with which results secured in the manufacturing process can be duplicated on a small scale. For this reason two commercial rock wools were analyzed, remelted, and blown. These wools, although differing widely in composition, were representative of materials obtainable on the market. The experimental data are given in Tables 15 and 16. The composition of sample A is perhaps the more representative of commercial samples.

It was difficult to distinguish any significant differences between the samples as received and after blowing. The changes recorded in fiber diameters and shot diameters are within the limits of experimental error. These results indicate that the experimental blowing tests afford a satisfactory means of judging whether the rock wool possibilities of a given deposit are worthy of further consideration.

TABLE 15—*Composition of commercial rock wools subjected to blowing tests*

	Sample "A"	*Sample "B"*
	Per cent	*Per cent*
SiO_2	36.9	44.0
Al_2O_3	19.5	10.3
Fe_2O_3	1.4	1.9
CaO	33.8	41.8
MgO	7.8	0.6
Miscellaneous	0.6	1.4

TABLE 16—*Results of experimental blowing tests on commercial rock wools*

	Sample "A"		*Sample "B"*	
	Remelted	*As Received*	*Remelted*	*As Received*
Pouring time (seconds)	36	....	34	....
Blast pressure (pounds per square inch)	70	....	70	....
Pouring temperature (degrees C.)	1500	....	1474	....
Av. fiber diameter (microns)	4	3	4	3
Av. shot diameter (microns)	38	37	44	40
Color	White	White	White	White

POSSIBILITY OF USING ROCK MIXTURES FOR THE PRODUCTION OF ROCK WOOL

Rocks, the compositions of which differ but slightly from those that yield satisfactory rock wools, are termed sub-woolrocks. A number of sub-woolrocks, as revealed by the rapid carbon dioxide test, were subjected to chemical analysis. The question arises whether these materials are suitable for the production of rock wool if the deficient ingredients are added in the manufacturing process. Very little has been published on such use of rock mixtures but it is reported that limestone is added to woolrocks in the Indiana district to correct for excess silica, and Thoenen *(3)** states that one manufacturer produces mineral wool from silica rock and calcite.

The amounts of added ingredients required to produce mixtures of satisfactory composition can be calculated if the limits of composition suitable for the production of rock wool are known. As discussed more fully in Chapter VII, rock wool can be considered in terms of a four-component system consisting of silica, alumina, magnesia, and lime. Such a system can be represented by a solid tetrahedron, each apex of which represents 100 per cent of one of the individual four components. Any composition containing these four components can be represented by a point in or on the surface, edges, or apexes of this tetrahedron (Fig. 19, p. 189). From the standpoint of securing satisfactory mixtures containing sub-woolrocks, three parts of this four-component system are of special significance. These are: (a) the silica apex; (b) a portion of the silica-alumina edge extending from SiO_2 60, Al_2O_3 40, to SiO_2 80, Al_2O_3 20 per cent which portion of the edge is rep-

* Italic numbers in parentheses refer to bibliography, p. 241.

resentative of the compositions furnished by calcined shales; and (c) a portion of the lime-magnesia edge extending from CaO 100, MgO 0, to CaO 58, MgO 42 per cent which is representative of the compositions obtained when rocks, varying in composition from pure limestone to pure dolomite, are calcined. A composition suitable for the production of rock wool can be obtained from any sub-woolrock containing any or all of the four components enumerated above, provided that a straight line, passing from the point representing the composition of the calcined sub-woolrock to one of these three parts of the tetrahedron, intersects the region of suitable composition shown in the composition diagrams (Figs. 20 to 28). It is also possible to secure a satisfactory composition from two sub-woolrocks, the calcined compositions of which lie on opposite sides of the region of suitable composition, provided that a straight line joining the points representing the compositions of the calcined sub-woolrocks intersects the region of suitable composition.

In every case where satisfactory compositions can be secured by admixture of other rocks, the question of whether or not such mixtures are practical depends upon factors which cannot be evaluated by small-scale blowing tests. Such factors include the proximity of the raw materials to each other, the quantity of deficient ingredient required to produce a satisfactory composition, ability to secure sufficient interaction between the ingredients of the mixture within the cupola, and the comparative ease or difficulty, with reference to the physical characteristics of the rocks, with which they can be accommodated by the cupola. Semi-plant scale operations will be required to secure much of this information.

The rock required to be added to a sub-woolrock is herein called a "flux rock." A flux rock may be a sandstone, clay, shale, limestone, or dolomite, depending upon the composition of the sub-woolrock with which it is to be used. In Table 18 are presented a number of calculated results of the amounts of flux rock required for certain sub-woolrocks. For purposes of calculation, it is assumed that shales used for fluxing would be composed of SiO_2 60 per cent, and R_2O_3 (chiefly Al_2O_3) 25 per cent, with an ignition loss of 10 per cent. This allows 5 per cent for all other impurities. It is similarly assumed that dolomite would average $CaCO_3$ 60 per cent, $MgCO_3$ 35 per cent, impurities 5 per cent. Variations from these values for flux rock will produce corresponding variations in the amount of flux rock required.

The range of compositions satisfactory for the production of rock wool is given by means of triangular diagrams, each of which represents a certain percentage of silica, i. e., 35 per cent, 40 per cent, 45 per cent . . . . 65 per cent SiO_2 (Chapter VII, Figs. 22-28). The most satisfactory method of determining correct proportions of mixtures appears to be that of calculating the amount of flux rock required per ton of sub-woolrock to give a mixture which will contain, on a calcined basis, a percentage of silica equal to that represented by one of the diagrams. The percentage of the remaining components of this mixture can then be calculated on a calcined basis and reference to the diagram for the percentage of silica chosen will show at once whether the mixture lies within the shaded portion of the diagram that represents the region of satisfactory composition.

A certain latitude is permissible in choosing the silica percentage upon which the calculation is made, but this is of small importance. Take, for example, sub-woolrock sample *DS-69* (Tables 17 and 18). This material is described as a shaly limestone and its analysis shows it to be deficient in silica and alumina. A shale flux-rock is therefore required. Preliminary considerations indicated that admixture of *DS-69* with shale to yield a mixture containing 40 per cent silica, on a calcined basis, should yield rock wool. The amount of flux-rock required for such a mixture is found to be 1010 pounds per ton of sub-woolrock. On calculating the mixture on a calcined basis, values of SiO_2 41 per cent, R_2O_3 19 per cent, MgO 4 per cent, CaO 37 per cent are obtained. Reference to figure 23 shows such a mixture to lie within the shaded area *EFG* and therefore to be suitable for rock wool production. If a similar calculation is made for a mixture containing 35 per cent SiO_2, the amount of flux-rock required is found to be 628 pounds per ton of sub-woolrock and the composition of the calcined mixture is SiO_2 35 per cent, R_2O_3 17 per cent, MgO 4 per cent, CaO 43 per cent, miscellaneous oxides 2 per cent. In making such calculations, the miscellaneous oxides can usually be neglected. Reference to figure 22 shows that this mixture lies on the very edge of the shaded area. A similar calculation made for a 45 per cent calcined silica mixture would probably yield a satisfactory composition but it would require an extremely large quantity of flux-rock. Therefore it can be concluded that a satisfactory mixture, as regards composition, can be obtained by mixing *DS-69* with shale to secure a composition on a calcined basis containing between 35 and 40 per cent silica.

In order to facilitate the calculation of the amount of flux-rock (expressed in pounds) required per ton of sub-woolrock, to secure a mixture of calcined material of a definite silica content, the following formula has been derived:

$$y = 2000 \frac{f_2}{f_1} \left\{ \frac{C - Af_1}{Bf_2 - C} \right\} \qquad \text{(I)}$$

y = weight of flux rock in pounds required per ton of sub-woolrock.
A = fraction of silica in sub-woolrock = per cent $SiO_2/100$.
B = fraction of silica in flux-rock = per cent $SiO_2/100$.
C = fraction of silica desired in calcined mixture = per cent $SiO_2/100$. (To make use of figures 22 to 28, C will be a multiple of 0.05, ranging from 0.35 to 0.65.)
f_1 = ratio of weight of sub-woolrock to weight of calcined sub-woolrock.
f_2 = ratio of weight of flux-rock to weight of calcined flux-rock.

Since f_1 and f_2 are ratios, it is immaterial in what units they are expressed. These ratios are most readily calculated from rock analyses, in which case they would be 100 divided by the sum of the percentages of permanent oxides, i. e.,

$100 \div (\%\ SiO_2 + \%\ R_2O_3 + \%\ MgO + \%\ CaO + \%$ miscellaneous oxides).

The derivation is:

$2000A$ = weight of SiO_2 in sub-woolrock.

yB = weight of SiO_2 in flux-rock.

$$\left\{ \frac{2000}{f_1} + \frac{y}{f_2} \right\} C = \text{weight of } SiO_2 \text{ in calcined mixture.}$$

$$\text{Now } 2000A + yB = \left\{ \frac{2000}{f_1} + \frac{y}{f_2} \right\} C.$$

Collecting terms gives:

$$y = 2000 \frac{f_2}{f_1} \left\{ \frac{C - Af_1}{Bf_2 - C} \right\} \qquad \text{(I)}$$

A more simple method of calculating the weight of flux-rock required per ton of sub-woolrock is based on the CO_2 content of the rocks in question. It has been shown that satisfactory woolrocks contain from 20 to 30 per cent CO_2 (Chapter VII). To secure a satisfactory mixture, it is merely necessary to calculate the weight of flux-rock required to give a carbon dioxide content of 25 per cent for the uncalcined mixture. This method, however, has several disadvantages. It is not as accurate as the method based on the silica content and it does not readily adapt itself to an estimation of the minimum amount of flux-rock required. For these reasons a close agreement between the results of the two methods of calculation cannot be expected.

The algebraic formulation of this method is as follows:

Let D = the percentage of CO_2 in the sub-woolrock.

E = the percentage of CO_2 in the flux-rock.

x = the number of pounds of flux-rock required per ton of sub-woolrock.

Then $$\frac{2000\,D}{100} = \text{weight of } CO_2 \text{ in sub-woolrock.}$$

$$\frac{xE}{100} = \text{weight of } CO_2 \text{ in flux-rock.}$$

$$\frac{(2000 + x)\,25}{100} = \text{weight of } CO_2 \text{ in mixture.}$$

Now $$\frac{2000\,D}{100} + \frac{xE}{100} = \frac{(2000 + x)\,25}{100}$$

from which,

$$x = 2000\,\frac{(25 - D)}{(E - 25)} \qquad \text{(II)}$$

The flux-rock requirements of certain sub-woolrocks are listed in Tables 17 and 18. These rocks are selected as illustrative and the list does not exhaust all possibilities within the State. Table 17 presents geological information and analyses of sub-woolrocks. Table 18 lists the type of flux rocks required, the amounts calculated on the basis of carbon dioxide content, and the amounts calculated on the basis of silica content. The compositions of the resultant calcined mixtures, calculated on the silica basis, are also presented.

The utilization of sub-woolrocks requires the location of suitable flux rocks in proximity to the sub-woolrock deposit. Two cases are presented in Table 18 where this has been done. Samples *DX-4* and *DX-5* are calculated on the ratio of thickness of the deposits, which are adjacent. Sample *NF-39* is an impure shale which may be mixed with *NF-38*, an impure dolomite. The geological section of this report (Chapters II-V) discusses a number of flux rocks which may be found useful.

TABLE 17—*Locations and chemical analyses of sub-woolrocks*

Sample No. (a)	Description	Thickness (feet)	County	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Misc.	CO_2
DS-18	Impure limestone above coal No 6	15	Perry	23.31	5.67	2.32	3.49	33.78	0.08	30.17
DS-55	Pennsylvanian limestone	15	Peoria	15.27	2.26	1.04	0.78	45.15	......	35.4
DS-69	Shaly limestone	14	Rock Island	13.42	5.13	2.41	3.75	39.30	......	34.73
DS-77	Maquoketa dolomite	26	Stephenson	11.74	4.82	1.29	16.64	25.73	......	36.90
DS-94	Richmond shale	?	Grundy	35.26	13.61	4.52	4.67	17.26	4.36	17.1
DX-4	Niagaran dolomite	15	Cook	24.84	1.13	1.85	15.01	22.99	......	34.29
DX-5	Niagaran dolomite	10	Cook	41.08	2.01	1.88	11.95	17.49	......	25.5
DX-18	Shakopee dolomite	26	LaSalle	16.10	6.57	1.60	13.98	24.05	......	37.19
DX-19	Shakopee dolomite	40	LaSalle	23.05	1.64	1.64	16.23	23.73	......	34.5
DX-20	Pennsylvanian limestone	24	LaSalle	16.83	4.32	2.06	1.95	40.35	0.86	32.94
NF-38	Niagaran dolomite	9	Kane	11.8	3.4		18.5	27.0	......	39.8
NF-39	Niagaran shale	2	Kane	45.4	10.3	1.8	8.8	11.7	4.6	18.2
NF-58	Niagaran dolomite	40	Cook	14.6	4.3		17.5	26.3	......	37.7
NF-69	Cap limestone of No. 6 coal	9	Perry	9.8	4.7		1.3	47.1	......	37.7
NF-71	Springville chert	6	Union	57.0	1.39	3.01	2.1	21.1	......	17.3
NF-84	Limestone between coals Nos. 5 and 6	6	St. Clair	15.3	3.1		0.6	45.4	......	35.9
NF-90	Cherty Osage limestone	35	Monroe	24.4	1.23		1.5	40.29	......	32.3
NF-95	Dolomite	5½	Kankakee	21.02	5.41	1.70	15.55	22.4	......	33.6

(a) For further information on samples listed, refer to Index of Sample Numbers, p. 243.

TABLE 18—*Flux-rock requirements of sub-woolrocks (a)*

Sample No.	Type of flux-rock required	Pounds of flux-rock per ton of sample		Calculated composition of resultant wool on SiO_2 basis				
		CO_2 basis	SiO_2 basis	SiO_2	R_2O_3	MgO	CaO	Misc.
DS-18	Shale (1)..........	414	348	40	15	4	40	1
DS-55	Shale (1)..........	832	870	40	14	1	44	2
DS-69	Shale (1)..........	776	628	35	17	4	43	2
DS-77	Shale (1)..........	952	1,035	40	18	16	24	2
DS-94	Dolomite (2)......	802	308	40	21	8	25	6
DX-4	DX-5 (*b*)..........	....	....	45	5	20	30	......
DX-18	Shale (1)..........	975	740	40	18	15	25	2
DX-19	Shale (1)..........	759	694	45	12	17	24	2
DX-20	Shale (1)..........	635	812	40	16	2	40	2
NF-39	NF-38............	....	1,066	45	12	16	23	4
NF-58	Shale (1)..........	1,017	874	40	15	17	26	2
NF-69	Shale (1)..........	1,017	1,280	40	17	1	39	3
NF-71	Dolomite (2).......	782	378	60	5	6	29	1
NF-84	Shale (1)..........	872	870	40	13	1	44	2
NF-90	Shale (1)..........	584	615	45	9	2	42	2
NF-95	Shale (1)..........	686	452	40	15	18	26	1

(1) Theoretical shale composition used for flux-rock:
SiO_2=60%; R_2O_3=25%; Impurities=5%; Ig. Loss=10%.

(2) Theoretical dolomite composition used for flux-rock:
$CaCO_3$=60%; $MgCO_3$=35%; i. e., CaO=33.6%; MgO=16.7%; CO_2=44.7%; Impurities=5%.

(*a*) For a list of sub-woolrocks found in Illinois, see Table 35, Appendix II.
(*b*) Calculated on the ratio of the thickness of the deposits; the densities of the two rocks are assumed to be equal.

RECOMMENDED PROCEDURE FOR THE DEVELOPMENT OF ILLINOIS WOOLROCK DEPOSITS

This survey of the woolrock resources of the State and the experimental determination of suitable composition limits for rock wool production have by on means exhausted the research problems pertinent to the production of rock wool. Many of these problems, however, are such as to require the operation of large scale equipment, and further investigation must rest largely with individual enterprise. It is, then, well to consider critically what is revealed by this investigation, what steps should be taken by individuals who may be interested in the development of a rock wool industry, and the possible difficulties that may attend the commercial development of any of these deposits. The results of this investigation do not prove that profitable exploitation of any one of the deposits is possible. Before this can be made certain, further development work is required.

Adequate exploration of possible woolrock deposits must include data on the following points:

(a) *Chemical composition.*—The rapid carbon dioxide test should provide an economical means for a preliminary evaluation, but before extensive operations are considered, complete analyses, both for major constituents and the more common impurities, should be available.

(b) *Extent of deposit.*—The extent of the deposits should receive primary consideration. This can be determined only from thorough exploration including drilling and analysis of the drill cores.

(c) *Physical character.*—The physical characteristics of the rock deposits should also be studied. Apparently finely pulverized materials cannot be used in a cupola (Appendix I). It is also impossible to predict how certain of the deposits which are not completely homogeneous, will react when treated on a large scale. For example, the Bailey limestone, which produces excellent wool when blown on a small scale, may require a somewhat special treatment.

(d) *Character of the product.*—The color of the product will be different when produced on a large scale. In most cases this should offer no difficulties. Certain materials which yield brown or light tan wools on a small scale probably can be made to produce a more satisfactory product when treated on a large scale. In addition, there remains the chance of introducing impurities in the rock wool from the coke used for melting. For this reason the chemical composition of the ash from the coke must also be taken into account.

The most satisfactory method for solving all these problems is afforded by the construction and operation of a pilot plant wherein the results of the laboratory research may be tested and any difficulties ironed out. This may be followed by the operation of a large scale unit, and finally, the duplication of this unit to as many units as are needed for the completed plant (*27*). Between each of these developments the engineering and technical data accumulated should be critically scrutinized, the product should be subjected to market tests, and the economics of the whole development should be thoroughly investigated.

Essential data which the pilot plant will supply are: (a) the maximum amount of fuel required per ton of product; (b) the extent to which fluxing can be carried in the conventional type of equipment; (c) the changes which must be made in commercial equipment to accommodate materials with unique physical properties; and (d) the operating conditions necessary for large scale production of a product having satisfactory color and fiber characteristics.

CHAPTER VII.—INFLUENCE OF VARIABLES ON THE PRODUCTION OF ROCK WOOL

INTRODUCTION

The two most important properties of rock wool are low heat conductivity and low bulk density. Therefore it would seem that a direct attack on the problem would consist in preparing samples of rock wool under varied conditions of temperature, blowing pressure, etc., and evaluating the wool by means of heat conductivity and density measurements. These two properties, however, are extremely susceptible to variation on handling of the rock wool. They are not independent of each other and the relationship between them is such that a minimum heat conductivity is exhibited at a bulk density of about 10 pounds per cubic foot (Appendix V). Single determinations of these properties are insufficient therefore to evaluate a wool; in order to secure an adequate characterization of each sample, a series of density and heat conductivity measurements would be required.

Since the bulk density and heat conductivity of rock wool are mutually dependent, it appears probable that both of these properties are determined by certain fundamental characteristics of the material. The basis of this relationship is revealed in the physical structure of the material, i. e., by the properties of the individual fibers which make up the wool. The fibers are extremely thin glassy rods which lie in a criss-cross manner. The wool, by virtue of its complex network, entraps air in spaces of such small dimensions that heat is not transferred by convection. These air spaces account for both the low heat conductivity and the bulk density of the wool.

The properties of the individual particles which compose rock wool are herein termed fiber characteristics. A number of these properties are easily altered by mechanical processes and because of this it is difficult, if not impossible, to obtain samples for examination which are representative of the whole. These easily altered fiber characteristics, such as ratio of weight of shot to weight of fibers, average shot diameter, fiber length, etc., are the properties which are changed by the various manufacturing processes employed in refining crude rock wool. However, there is one property, namely, the average diameter of the fibers, which remains relatively unchanged by such treatment. The constancy of this property provides a convenient means of evaluating the various samples of rock wool produced experimentally.

The average fiber diameter is, in turn, governed by two sets of conditions. These are (1) operating conditions, such as pouring temperature, blast pressure, nozzle characteristics, rate of pouring, etc., and (2) physical properties of the melt, including viscosity, surface tension, density, and homogeneity. The art of rock wool production deals with the proper manipulation of the operating variables, whereas the scientific aspects of the subject involve the formulation of operating conditions as a function of the physical properties of the molten silicate mixtures. These physical properties are in turn functions of composition and temperature. This makes possible a practical approach to the problem in terms of composition and temperature.

In addition to fiber characteristics, certain chemical considerations, which affect the stability and color, must be taken into account in evaluating the quality of rock wool. The inter-relationships of the principal factors are

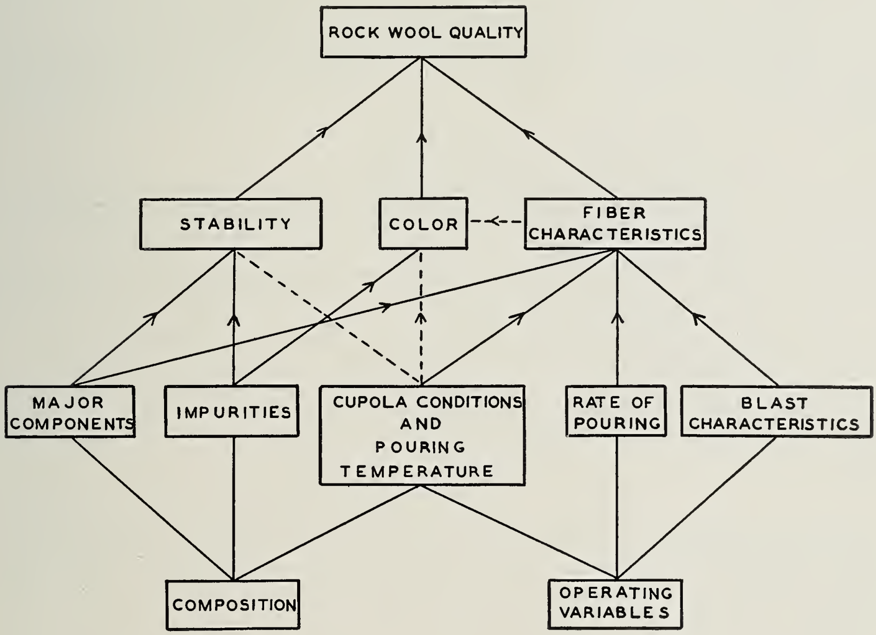


FIG. 15. Diagram showing inter-relationships of the principal factors influencing the quality of rock wool.

shown graphically in figure 15. This diagram indicates a logical presentation of the subject under three major headings, (1) the quality of rock wool, (2) the influence of operating variables on the production of rock wool, and (3) a study of the range of composition suitable for the production of rock wool.

Inasmuch as certain experimental data, presented in Chapter VI, are used to formulate the influence of pouring temperature, etc., and the topic of rock mixtures, also treated therein, is based on data presented in this section, a chronological presentation of the steps taken in the chemical investigation will outline our objectives.

1. Tentative formulation of limits of composition suitable for rock wool:
    a) by correlation of information in the literature;
    b) by analysis of commercial samples of rock wool.
2. Selection of samples falling within the above limits:
    a) by means of rapid CO_2 determinations; followed by
    b) complete analysis of the rock samples which showed CO_2 values lying between the tentative limits of 20 and 30 per cent.

3. Experimental blowing tests on samples, the compositions of which were within or close to the tentative limits. These experiments also yielded information on the influence of experimental conditions on quality of the products and rendered the tentative composition limits more definite.

4. Final formulation within the four-component system (silica-alumina-lime-magnesia) of limits of composition suitable for rock wool production from:
    a) information in the literature;
    b) analyses of commercial wools;
    c) information secured by experimental testing of Illinois raw materials;
    d) synthetic mixtures, made up and subjected to the experimental blowing test.

5. A brief investigation of impurities in relation to color.

THE QUALITY OF ROCK WOOL PRODUCED EXPERIMENTALLY

Stability

Rock wool shows one type of stability in its resistance to devitrification when subjected to high temperatures, and another type which is dependent on the absence of certain impurities that on hydrolysis yield corrosive substances or give obnoxious odors.

As may be inferred from observations on common glass, a devitrifying tendency over a long period of time may be expected since both glass and rock wool are undercooled liquids. When rock wool is used as a high temperature insulating medium, its devitrifying tendency will be accentuated since the velocity of crystal growth in vitreous materials is increased with elevation of temperature. It is to be expected that wools of different compositions will exhibit varying degrees of resistance to devitrification.

Representative samples of wool of each of the various compositions listed (Table 14, p. 162) were heated in porcelain crucibles for two hours each at 500°, 600°, 700°, 800°, and 900°C. respectively in order to observe their devitrification and sintering characteristics. It was found that these materials disintegrated to various degrees at 800°C. Those samples which exhibited a brown or tan color were darkened by heating at 700°C. The 800° heat-treated samples also revealed the formation of crystals when examined microscopically under crossed nicols, thus demonstrating that the disintegration of the wool is accompanied by devitrification. These tests were significant in that all the samples of satisfactory color prepared from Illinois raw materials showed temperature stability on a par with the commercial samples described in Table 15 (p. 167).

With regard to the second type of stability, impurities, such as calcium sulphide or sulphate, are reported as generating on hydrolysis bad odors and substances which corrode steel. However, after the experimental results on the influence of impurities on color were obtained, it was evident that tests as conducted in this investigation on the Illinois woolrocks would not yield information of value since the amounts of sulphur compounds present in the finished wool were found to be subject to variation with certain changes in operating conditions.

Color

The influence of fiber characteristics on color is relatively slight, and may be summarized in the statement that the finer the fibers, the lighter will be the color. Examination of commercial material indicates that insofar as rock wool shows a tint it can often be ascribed to the presence of colored shot rather than to colored fibers.

The major components, i. e., silica, alumina, lime, and magnesia, produce a pure white rock wool but small amounts of certain compounds seriously affect the color. Rocks listed in Table 14 as giving light tan and brown wools were found to contain variable amounts of iron and manganese compounds. From the odors generated in fusing the rocks, it was evident that sulphur compounds were also present.

Although analyses showed that the color could be ascribed to certain materials present in small amounts, they gave no indications of what elements or combination of elements were responsible. Experiments devised for obtaining this information consisted in producing colored wools from synthetic mixtures. To mixtures of calculated composition, SiO_2 49.5, Al_2O_3 10.0, CaO 31.5, and MgO 9.0 per cent, were added varied amounts of different compounds. The wools were blown under standardized experimental conditions. Results are shown in Table 19.

Although these experiments do not exhaust all possibilities, the results are suggestive. Iron oxide in fairly large quantities had but little effect upon color. This is in agreement with the fact that a number of commercial wools have been found to contain a high percentage of iron and yet were satisfactory from a standpoint of color. Ferrous iron gives a very pale green tint to wool. Small amounts of manganese oxide were found to impart no color. The concentration of the material was slightly greater than that found in naturally occurring rocks which yielded highly colored wools. Sulphur was added to the synthetic mixtures in the form $CaSO_4.2H_2O$. Alone, or in the presence of small amounts of MnO, it produced no coloration but when iron oxide was present a deeply colored brown wool was obtained. The color of samples containing iron and sulphur resembled the color of certain of the wools described in Table 14, and it is probable that these elements were responsible for the color.

Sulphur occurs most commonly in Illinois rocks in the minerals pyrite and gypsum. Since sulphurous vapors were evolved from certain woolrocks at 1500°C., a duplicate of the synthetic sample containing iron and sulphur was heated for 45 minutes at this temperature. This is three times as long as the standard time of heating. The wool so produced was white. This experiment suggests that those samples listed in Table 14 which yielded brown wools would yield satisfactory wools as regards color, if so treated as to eliminate the sulphur compounds, i. e., if treated at somewhat higher temperatures and for longer heating periods.

TABLE 19—*The influence of impurities on color of rock wool (a)*

Sample No.	Impurities added	Color
25–A	3.07 grams MnO_2	white
25–B	57.2 grams Fe_2O_3	white
25–C	3.07 grams MnO_2 + 57.2 grams Fe_2O_3	white
25–D	54.0 grams $CaSO_42H_2O$ + 57.2 grams Fe_2O_3 + 3.07 grams MnO_2	brown
25–E	52.7 grams pulverized Illinois coal	white
25–F	57.2 grams Fe_2O_3 + 54 grams $CaSO_42H_2O$	brown
25–G	3.07 grams MnO_2 + 54 grams $CaSO_42H_2O$	white
25–H	54 grams $CaSO_42H_2O$	white
25–I (*b*)	54 grams $CaSO_42H_2O$ + 57.2 grams Fe_2O_3 + 3.07 grams MnO_2	white

(*a*) Procedure: To one kilogram of material, with a composition SiO_2 49½, Al_2O_3 10, CaO 31½, and MgO 9 per cent, were added weighed amounts of impurities. The amounts of impurities were suggested by analyses of woolrocks yielding colored wools. The mixtures were blown under standardzed conditions, i. e., 15 minutes heating at 1500° C., 35 seconds pouring time, and 70 pounds blast pressure.

(*b*) Sample 25–I heated 45 minutes at 1500° C.

Fiber Characteristics

Rock wool consists of an aggregate of thin interlaced glassy rods interspersed with beads or shot (Fig. 16). The overall heat conductivity of the wool is the resultant of two conductivities, (1) that of the air entrapped by the tangled fibers and (2) that of the solid, individual fibers. If the wool is loosely piled, that is, exhibits a low bulk density, the air pockets are large enough to permit heat transfer by convection; if the wool is closely compressed, heat can be readily conducted by the solid, glassy portion of the system. Therefore rock wool shows relatively high heat conductivities at both high and low bulk densities. The lowest heat conductivity occurs at some intermediate density. Under the optimum conditions the conductivity of the solid phase has little influence and the conductivity of the rock wool system as a whole approaches a limiting value determined by the conductivity of still air.

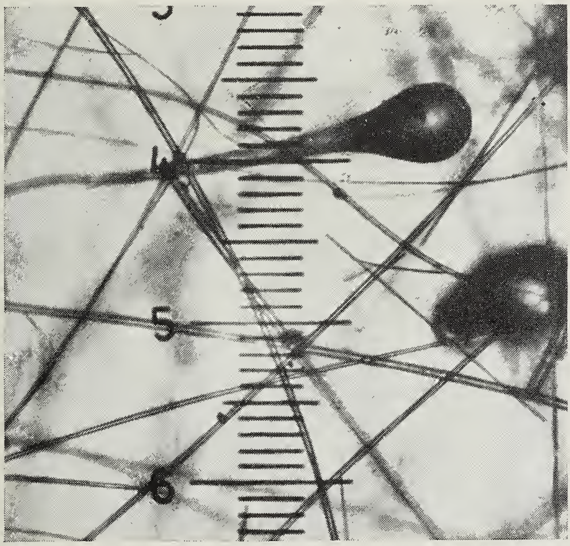


FIG. 16. Photomicrograph of rock wool showing fibers and shot. One division of the scale is equal to 10 microns. (One micron is 1/1000 millimeter.)

Since both the heat conductivity and the bulk density of rock wool are properties which are easily altered by handling, and are determined by the fiber characteristics, it has seemed desirable to determine which of the fiber characteristics, if any, are not susceptible to variation. The following is a list of characteristics:

A. Characteristics not susceptible to alteration:
   1) Average fiber diameter. Alterable only with difficulty by some process of picking or blowing.

B. Characteristics which are easily altered:
   1) Average shot diameter. Shaking or handling causes the larger shot to fall out of the wool, thus altering the average diameter.
   2) Ratio of weight of shot to weight of fibers. Readily altered by vibration.
   3) Length of fibers. Readily altered by mechanical operations.

The last three characteristics are those which are altered in the various manufacturing processes used for refining rock wool. Wool which is to be blown into the walls of houses is subjected to crushing, shaking, and perhaps air separation, thus altering the fiber lengths, average shot diameter, and ratio of weight of shot to fiber. While it cannot be said that the average fiber diameter is absolutely unalterable, it is much more constant than the other characteristics.

An inspection of the various samples of rock wool produced in this investigation is sufficient to indicate the part played by the average fiber diameter in determining the bulk properties of rock wool. Those which naturally possess a high bulk density, with probable high heat conductivity, are invariably characterized by extremely fine fibers. On the other hand coarse fibered wools are extremely bulky and unpleasant to handle. These latter wools would undoubtedly exhibit high heat conductivities because the entrapped air pockets would not be small enough to prevent convection. Between these extremes are found wools of satisfactory bulk which are characterized by fiber diameters lying between 2 and 10 microns. Such wools are soft and exhibit quite a degree of resiliency. The average fiber diameter is, therefore, believed to be a valuable criterion for the evaluation of rock wool quality. It is determined by melt composition, pouring temperature, blast characteristics, and pouring rate.

THE INFLUENCE OF OPERATING VARIABLES ON THE EXPERIMENTAL PRODUCTION OF ROCK WOOL

The objectives in the study of the influence of operating variables on the experimental production of rock wool were, first, to provide a standardized procedure by means of which the composition range could be rapidly delineated, and, second, to determine the trend to be expected by variation of the individual operating conditions.

For a detailed description of equipment and experimental procedure, the reader is referred to Appendix III. Only experimental results are considered in the present chapter. The data on the influence of operating variables were obtained on Illinois raw materials, reported in Table 14 of Chapter VI.

Pouring Temperature

No attempt was made to measure the temperature of the molten rock stream at the moment it entered the steam blast. The temperature of the molten rock or synthetic mixture, as the case might be, was measured just prior to pouring and after temperature equilibrium had been attained in the crucible. During the pouring interval, the high frequency crucible current was held constant, so that the only difference in temperature between that measured and that exhibited by the rock stream at the moment of meeting the steam blast, was due to heat losses suffered in falling about six inches

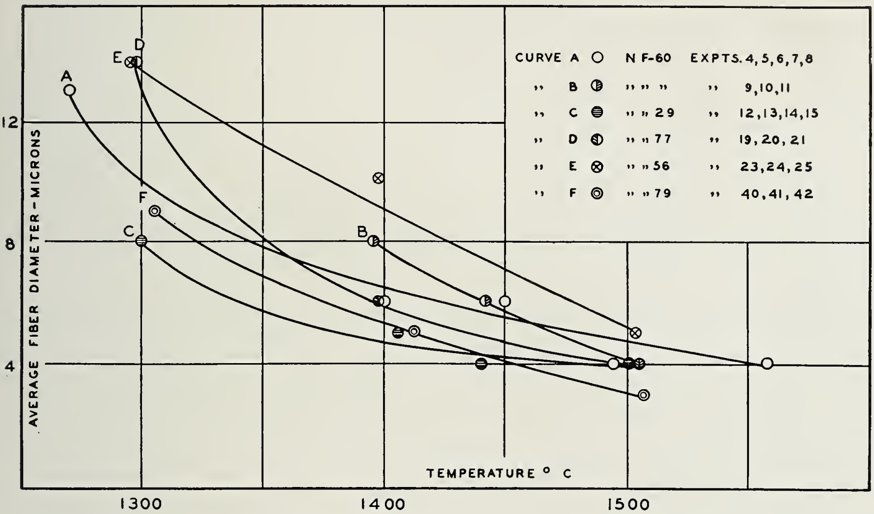


Fig. 17. Variation of fiber diameter with pouring temperature (See Tables 13 and 14).

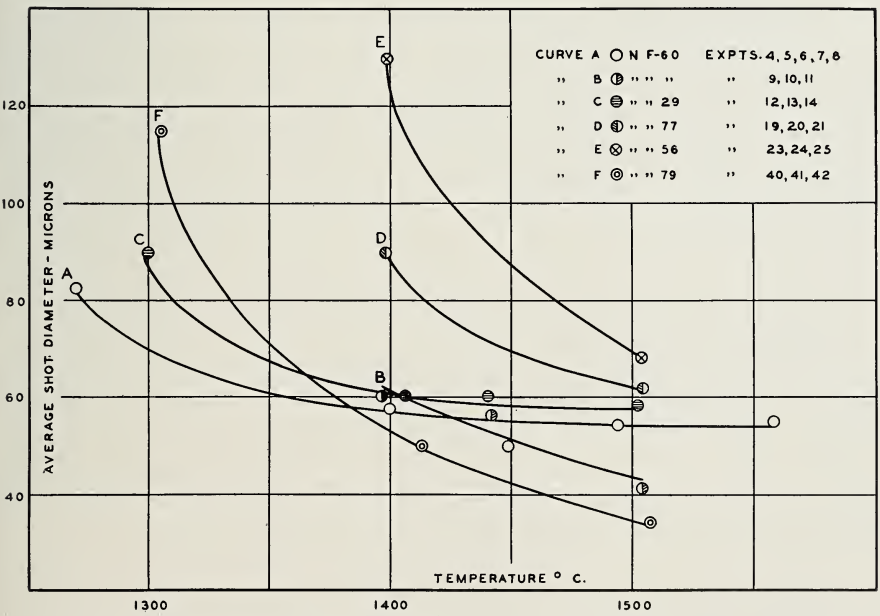


Fig. 18. Variation of shot diameter with pouring temperature (See Tables 13 and 14).

from the crucible lip. It is reasonable to expect that this temperature drop was constant for all experiments conducted at the same temperature.

Various groups of experiments listed in Table 14 show the influence of pouring temperature on fiber characteristics. These groups include experiments 4, 5, 6, 7, and 8; 9, 10, and 11; 12, 13, 14, and 15; 19, 20, and 21; 23, 24, and 25; and 40, 41, and 42. The fiber diameters and shot diameters are plotted in Figs. 17 and 18. It will be observed that increasing the temperature decreases the shot and fiber diameters. This decrease is accompanied by an increased softness to touch, lighter color, and higher bulk density.

All the rock samples tested contained sufficient potash and other volatile components to produce a condensation smoke over the crucible charge. This interfered with radiation and prevented the use of an optical pyrometer. Temperature measurements, therefore, were not made higher than 1550°C., the upper useful limit of platinum-platinum 10 per cent rhodium thermocouples.

A temperature of 1500°C. was selected for the standardized procedure. It should be mentioned that certain compositions studied might be of practical value provided that higher pouring temperatures were used. Compositions exhibiting fiber diameters of 10 microns or higher fall in this class.

Steam Blast Characteristics

In this category are included pressure drop across the nozzle, nozzle design, and medium used for blowing, i. e., steam or compressed air. The pressure drop could be readily controlled and the experimental results of this variation are given in Table 14, experiments 6 and 9; and 15, 16, and 17. According to these experiments, variation of pressure within the limits shown does not cause an appreciable change in the fiber and shot diameters. However, certain preliminary experiments, which are not reported, give reason to believe that the number of shot is increased by further lowering of the pressure. This produces a heavy wool containing excessive amounts of shot.

Experiments 48 to 64 are not reported in Table 14. The reason for their omission is of some importance. They were made at a time when dry steam was not available and it was found that wet steam seriously affected the properties of the wools giving heavy products consisting largely of shot.

The design of the nozzle is described in Appendix III. Several nozzle orifices were tried before one which worked satisfactorily was obtained. The same nozzle was used in all experiments described in this report.

Pouring Rate

Experiments 1, 2, and 3 (Table 14) show that variation in the rate of pouring has little influence on the fiber and shot diameters. However, as the rate of pouring is increased the number of shot produced increases. In some preliminary experiments conducted for establishing a satisfactory rate of pouring, large quantities of shot were obtained at high pouring rates. These results indicate the possibility of obtaining a shot-free product by more slowly pouring the molten silicates into the blast. A more economical method of attaining the same objective, however, probably lies in careful design of the steam nozzle.

Except for experiments 2 and 3, all the melts were poured at the same rate of tilting. The variations in the pouring time noted in Table 14 are the result of variations of viscosity of the melt either with temperature or composition. The rate of pouring in experiments conducted on synthetic mixtures was not measured, but the rate of tilting the crucible was constant.

RANGE OF COMPOSITIONS SUITABLE FOR THE PRODUCTION OF ROCK WOOL

To evaluate the woolrock deposits of a geographical area, the information most useful is an accurate knowledge of composition limits. In anticipation of future inquiry on the part of those interested in rock wool production, a study of this type was undertaken.

Four lines of evidence have focused attention on the advantage of considering the composition of rock wool in terms of a four-component system consisting of silica, alumina, lime, and magnesia. Any substance not included in this system is considered an impurity. Data utilized in this study have been obtained from (1) information obtained from the literature; (2) analyses of commercial rock wools; (3) experimental production of rock wools from Illinois deposits the compositions of which were determined; and (4) the experimental production of rock wools from synthetic mixtures of oxides. By considering the subject in terms of a four-component system, it is possible to present information relative to the permissible composition range accurately and concisely in a series of graphs.

Previous Work and Results of Analyses of Commercial Wools

Lang (*1*) states that slags rich in iron (whether ferrous or ferric is not indicated) produce shot and no wool, while basic slags produce only short fibered wool or dust. A long range of viscosity is required to produce long fibers. The use of copper smelting slags rather than blast furnace slags is recommended.

Three authors (*3, 5, 6*) report maximum and minimum limits of composition which produce good wools. Two of these comparisons are given for woolrocks and must be recalculated to a calcined basis to be compared with the results of our investigation (Appendix II). The data on maximum and minimum limits of Thoenen (*3*) are not given in a form which permits of comparison without making certain assumptions regarding the permissible variations in CO_2 and MgO. Logan (*6*) reports composition limits resulting from the analysis of twenty samples of mineral wool. Goudge's data were obtained by experimentation. Those listed under Illinois Geological Survey are taken from the four-component diagrams (Figs. 20 to 28).

TABLE 20—*Calculated minimum and maximum limits of composition of rock wool*

	Thoenen (*3*)	Goudge (*5*)	Logan (*6*)	Ill. Geol. Survey
SiO_2	39.3–46.5	33.7–44.3	22.5–49.2	$<$35–65
R_2O_3	13.5–16.1	13.7–21.2	5.4–15.4	0–33
CaO	21.3–32.5	21.4–30.6	21.0–68.1	$<$ 5–50
MgO	11.6–16.8	13.3–18.9	4.0–18.8	0–32

Limits, as represented in Table 20, appear to include compositions from which wools cannot be prepared. There is no danger of such being the case when the composition diagrams (Figs. 20 to 28) are used.

The limits established by this investigation are with two exceptions wider than those calculated from previously reported data. Contrary to published information, it has been established that neither alumina nor magnesia is essential to the production of rock wool. Satisfactory wools have been produced from silica and lime. Some experimental evidence indicated the possibility of producing rock wool from alumina, silica, and magnesia, but since rocks containing only magnesia without lime are not to be found in Illinois, an investigation of this possibility was not made.

A number of mineral wool analyses, as recorded in the literature, are presented in Table 21. The published slag wool analyses show a wider range of compositions than do rock wool analyses. Slag wool may contain considerable amounts of iron, manganese, calcium sulphate, etc., dependent upon the type of slag from which it is manufactured. Rock wool, on the other hand, consists chiefy of SiO_2, Al_2O_3, CaO, and MgO, with small amounts of impurities such as TiO_2, FeO, Na_2O, K_2O, and S compounds.

Goudge (*5*) and Logan (*6*) have pointed out that mineral wools consist, in general, of a 50-50 mixture of acidic and basic oxides. Logan calculated this ratio on the basis of percentage compositions, whereas Goudge calculated a ratio of weighted acids to bases. Following Goudge's method, with the exception that Fe_2O_3 and Al_2O_3 are always included with the acids (the small amount of iron compounds present in rock wool causes in most cases no appreciable difference), a column marked A/B is included in Tables 21 and 22. A is the sum of the number of gram mols of SiO_2, Al_2O_3 and Fe, (calculated as Fe_2O_3) present in 100 grams of material, while B is a similar value for CaO and MgO. The calculation is not made for compositions containing excessive amounts of Fe, Mn, or other miscellaneous compounds. The data presented in Table 22 were obtained in this laboratory by analyzing samples of commercial mineral wools. The average of 19 such ratios is 1.032, but fairly wide deviations from this mean are recorded. It may be noted that the ratio of acidic components to basic components has a value of approximately 0.3 for cement rock and about 6.0 for soda-lime glass.

TABLE 21—*Published mineral wool analyses*

No.	Reference	Type	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Misc.	(*a*) A/B
1	Thoenen (3)	Slag wool	38.0	11.0	1.0	28.0	19.0	3.0	.770
2	Thoenen (3)	Slag wool	38.4	10.5	0.7	31.5	15.3	3.6	.793
3	Thoenen (3)	Rock wool	42.8	1.4	....	51.7	2.8	1.3	.734
4	Powell (23)	Prior art formula	40	17	6	21	13	3	1.251
5	Powell (23)	Improved formula	57	12	5	15	9	2	2.241
6	Green and Edwards (17)	Slag wool	30.9	24.7	0.5	35.6	....	8.3 (?)	....
7	Guttmann (4)	Slag wool	32.3	19.0	(*b*) 0.7	39.7	5.0	3.3	.875
8	Guttmann (4)	Slag wool	33.0	19.9	(*b*) 0.7	40.0	3.4	3.0	.939
9	Guttmann (4)	Slag wool	30.5	14.2	(*b*) 0.5	32.9	4.0	(*c*) 17.9	....
10	Guttmann (4)	Slag wool	34.0	13.6	(*b*) 1.7	44.4	2.5	3.8	.831
11	Guttmann (4)	Slag wool	34.0	9.1	2.7	38.7	6.2	(*d*) 9.3	....
12	Logan (6)	Mineral wool	36.4		(*e*) 12.2	32.7	18.8	....	.692
13	Logan (6)	Mineral wool	40.8		(*e*) 12.6	28.9	17.7	....	.842
14	Logan (6)	Mineral wool	34.1		(*e*) 11.2	44.1	10.6	....	.646

(*a*) A=gram mols of SiO_2, Al_2O_3, and Fe (calculated as Fe_2O_3) in 100 grams of material.
B=gram mols of CaO and MgO in 100 grams of material.
(*b*) FeO instead of Fe_2O_3.
(*c*) MnO=15.0 per cent.
(*d*) MnO=4.7 per cent, CaS=3.8 per cent.
(*e*) $Al_2O_3 + Fe_2O_3$.

TABLE 22—*Analyses of samples of commercial mineral wool*

No.	Type of material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Misc.	(*a*) A / B
1	Rock wool..........	40.1	18.6	1.7	28.1	11.1	0.4	1.110
2	Rock wool..........	36.9	19.5	1.4	33.8	7.8	0.6	1.021
3	Rock wool..........	37.1	11.9	1.2	33.4	15.6	0.8	.756
4	Rock wool..........	34.5	16.1	0.7	29.8	18.2	0.7	.749
5	Mineral wool........	38.0	15.3	6.8	17.9	19.8	2.2	1.020
6	Rock wool..........	41.8	13.2	0.7	25.5	18.2	0.6	.915
7	Rock wool..........	44.0	10.3	1.9	41.8	0.6	1.4	1.113
8	Slag wool...........	39.5	37.6		15.1	7.0	0.8	2.316
9	Mineral wool........	36.3	13.1	20.4	27.2	2.4	0.6	....

(*a*) A=gram mols of SiO_2, Al_2O_3, and Fe (calculated as Fe_2O_3) in 100 grams of material.
B=gram mols of CaO and MgO in 100 grams of material.

The question whether these ratios should be calculated on a percentage basis or molecular weight basis is of some interest. In optical glass it has been found that potash can be replaced by soda on a percentage basis (*30*). Since rock wool is a vitreous material, it might be expected that the percentage method would also suffice. The experimental results obtained in this investigation, however, indicate that calculations based on molecular ratios are preferable. When, for example, the fiber diameters of synthetic rock wools produced under standardized conditions are plotted as a function of the molecular ratio of acids to bases, a smoother curve is obtained than when they are plotted against the percentage ratio of acids to bases.

Experimental Determination of Composition Limits

The materials utilized in preparing synthetic mixtures consisted of amorphous silica, aluminum hydroxide, pulverized limestone (calcium carbonate) and hydrated magnesium carbonate. The weights of the various ingredients required for the mixtures were calculated from chemical analyses. The mixtures were made up to weigh one kilogram each on a carbon dioxide-free basis. The weighed ingredients of each mixture were placed in a pail, stirred thoroughly and transferred to a fireclay sagger. The mixtures were then calcined in a kiln at 1050°C. for three hours to remove carbon dioxide.

The blowing tests consisted in heating these samples at 1500°C. for 15 minutes and pouring into the steam blast maintained at 70 pounds nozzle pressure. The rate of tilting was the same in all cases, giving, except for the most viscous melts, an average pouring time of about 35 seconds.

To facilitate the plotting of experimental results, samples were made up to pre-determined compositions. In Table 23 the chemical analyses of a number of experimental rock wools, selected at random from the total number blown, are compared with these "batch" compositions. The average deviation of analytical values from "batch" composition values is ±0.7 per cent.

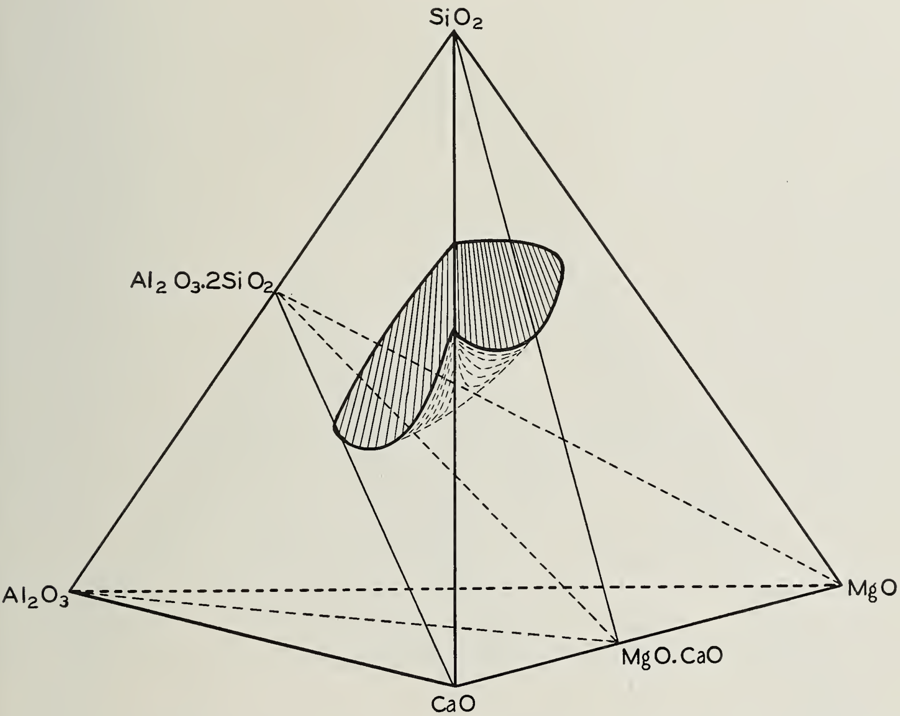


FIG. 19. Diagrammatic representation of composition range suitable for rock wool production.

The experimental data obtained on synthetic mixtures are summarized in Table 24. Composition diagrams (Figs. 19 to 28) are presented in order to visualize these results. These diagrams represent plane sections of an equilateral tetrahedron (Fig. 19). In such a tetrahedron, pure components are represented by the apexes; binary systems by the edges; ternary systems by the triangular exterior surfaces; and the various compositions comprising the quaternary system are represented by points within the tetrahedron. Thus figures 20 and 21 represent portions of two surfaces of this tetrahedron, namely the alumina-silica-lime ternary and the lime-silica-magnesia ternary. The remaining figures are parallel cross-sections of the tetrahedron on which are plotted mixtures containing amounts of silica constant for each cross-section.

The various compositions expressed in terms of weight per cent are represented by points on these diagrams in the usual manner of plotting on triangular co-ordinates. The sum of the four co-ordinates of any point is 100. In figures 22 to 28, 100 is obtained by adding the percentage of silica to the sum of the other three components, as given by their co-ordinates.

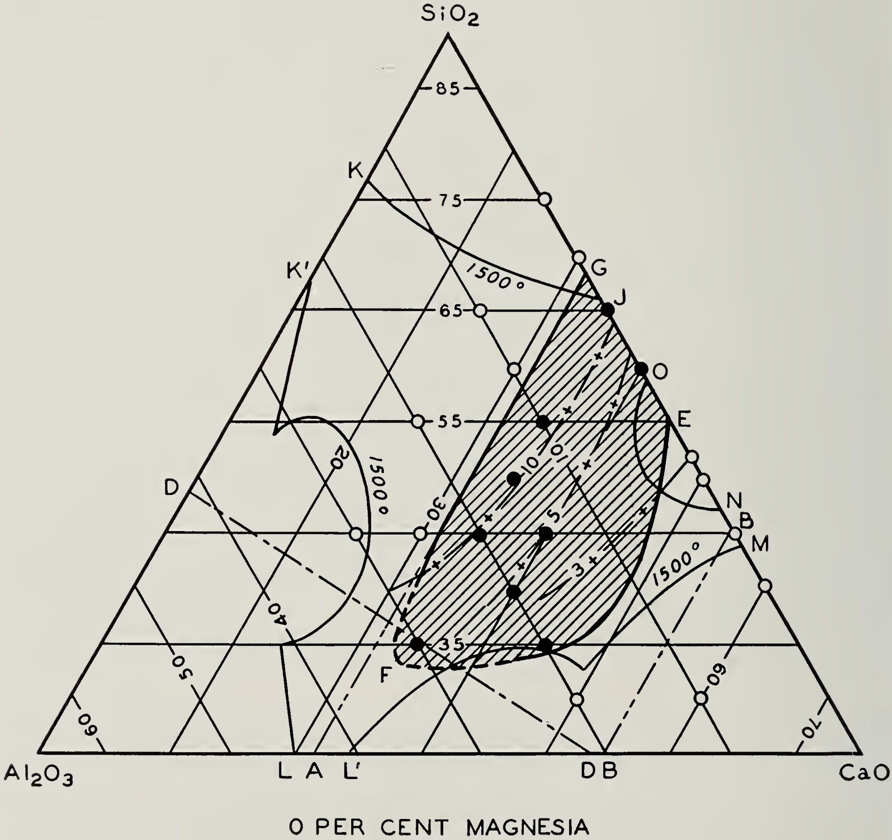


FIG. 20. Diagram showing range of compositions suitable for rock wool production in the ternary system consisting of SiO_2-Al_2O_3-CaO.

Before proceeding to a detailed examination of these composition diagrams, certain natural restrictions to the range of suitable rock wool compositions may be advantageously discussed. At first it might appear that any composition within the four-component system, which composition is capable of yielding suitable rock wool, would be important. However, there are a number of such compositions which probably do not occur naturally in rocks within the State of Illinois. None of the clays or shales was found to exhibit an alumina-to-silica ratio higher than that in kaolinite, namely 1 molecule of alumina to 2 molecules of silica. Extrapolation of the boundaries of the suitable composition areas in figures 22 to 28 to the 30 per cent silica cross-section would lead into a region of compositions requiring more alumina than occurs naturally. Therefore it is unnecessary to consider mixtures con-

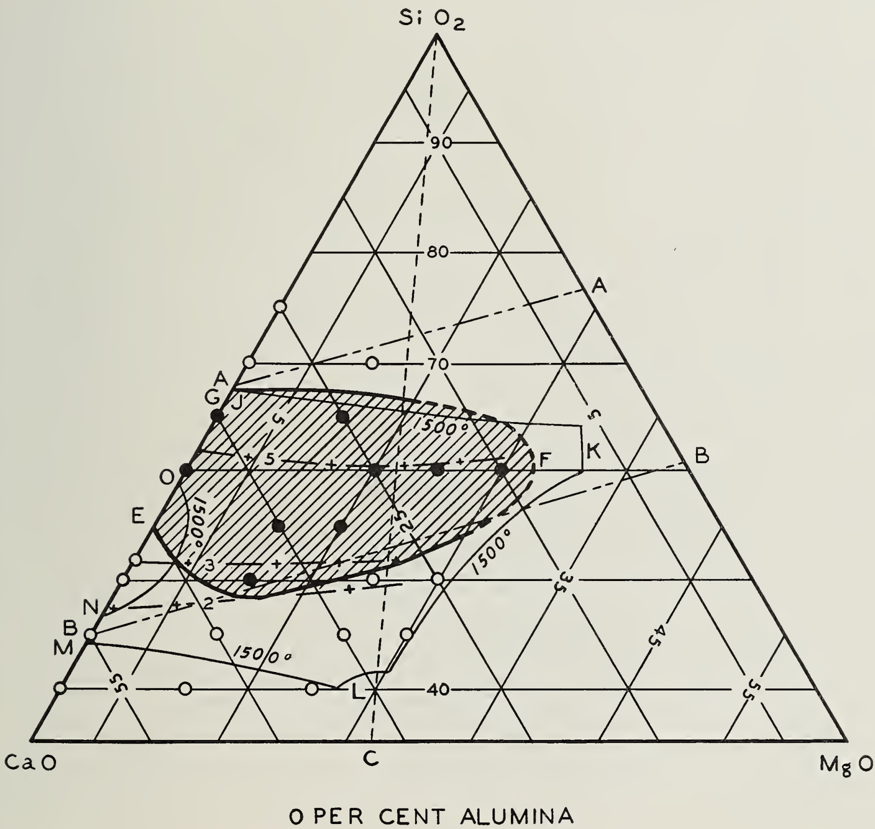


FIG. 21. Diagram showing range of compositions suitable for rock wool production in the ternary system consisting of SiO_2-CaO-MgO.

taining 30 per cent or less of silica. Likewise, magnesia does not occur in Illinois rocks in appreciable excess of the amount in which it occurs in the mineral dolomite, namely, in the ratio of 1 molecule of magnesia to 1 molecule of lime. Although certain compositions lying beyond these limitations have been studied for the purpose of securing an adequate picture of the composition limits, no effort has been made to determine these limits with the care accorded that portion of the four-component system which includes compositions available from naturally occurring rocks. The importance of these limitations is emphasized by the lines *DD,* representing compositions exhibiting the ratio of 1 molecule of alumina to 2 molecules of silica, and *CC,* representing the compositions exhibiting the ratio of 1 molecule of lime to 1 molecule of magnesia.

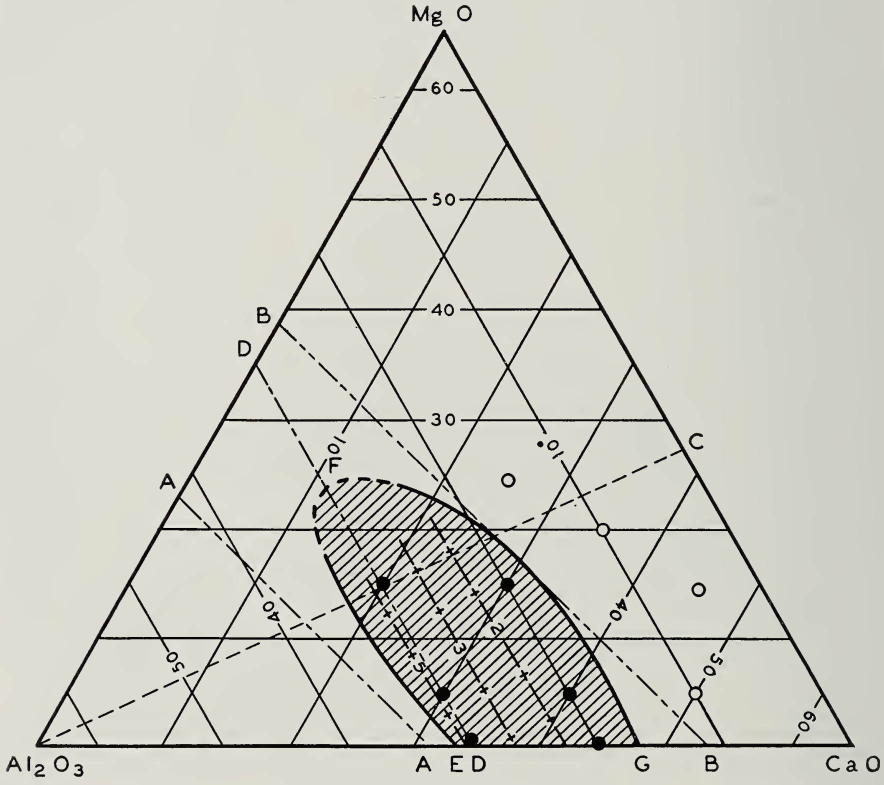


Fig. 22. Diagram showing range of compositions suitable for rock wool production in the quaternary system consisting of SiO_2-CaO-MgO-Al_2O_3 at 35 per cent silica.

In a solid tetrahedron representing the four-component system, these kaolinite and dolomite ratios are represented by two planes, which, by their intersection, cut the tetrahedron into four solid segments, only one of which is of practical importance.

The diagram figure 20 represents a portion of the ternary system Al_2O_3–SiO_2–CaO. The solid circles represent experimental wools which appeared satisfactory for insulation. The area enclosed by the heavy line *EFG* represents a range of composition suitable for the production of rock wool. The lower, dotted section of this line has not been accurately determined, but it will be noted that the suitable composition area, if it were extended, would fall beyond the line *DD*, i. e., into a composition range in which the alumina-to-silica ratio is higher than the kaolinite ratio. Since there is no magnesia in this system, there can be no line representing the dolomite ratio.

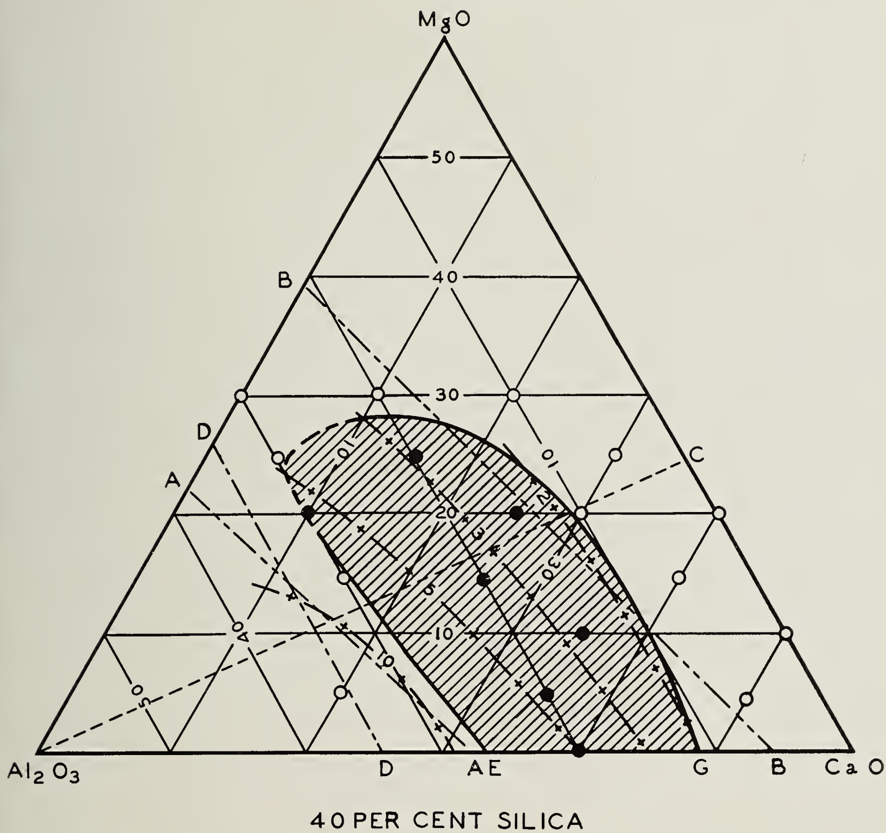


FIG. 23. Diagram showing range of compositions suitable for rock wool production in the quaternary system at 40 per cent silica.

The open circles indicate compositions which are unsatisfactory. Those in the lower right hand area of figure 20 represent, in most cases, soft and short fibered wools. Two of these samples could not be blown, and on cooling, underwent "feathering" (a phenomenon encountered with certain portland cement compositions), i. e., they crystallized and fell to a powder. The unsatisfactory compositions represented in the upper left hand area produced wools which were too coarse and prickly to be of value. These compositions might show more promise if higher blowing temperatures were used.

The solid line *JKLMNO* is the 1500°C. isotherm, as given in International Critical Tables (*31*). The position of certain experimental points with respect to this line shows that wools can be blown from the liquid phase

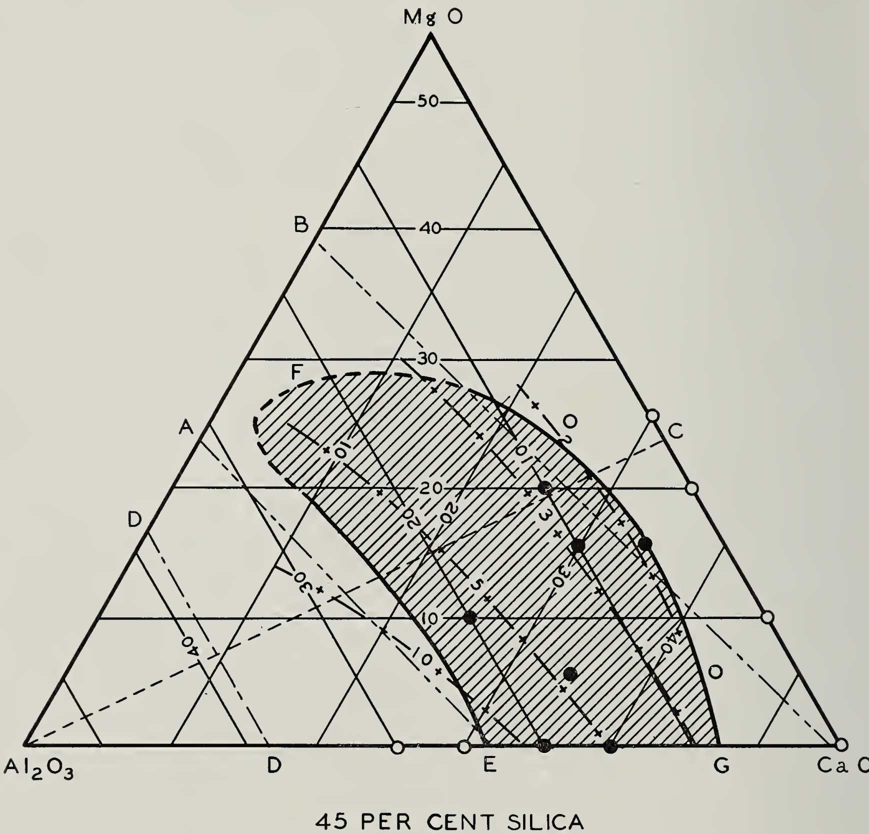


FIG. 24. Diagram showing range of compositions suitable for rock wool production in the quaternary system at 45 per cent silica.

even though the whole sample does not melt completely at the temperature at which it is blown. Such wools, however, are inclined to be unsatisfactory and the yield is low. Apparently this condition is encountered to some extent in commercial practice and may be responsible for the periodic shut-downs required to rake "lime" out of the cupolas (*2*). If the compositions used in practice fall inside of the isotherm representing the temperature at which the wool is blown, and if sufficient time is given the charge in the cupola to attain thermal and chemical equilibrium, such periodic shut-downs should not be necessary. Unfortunately, the isotherms have not been determined for portions of the four-component system other than those comprising the three-component boundary systems. Therefore, it is necessary to proceed empirically as regards thermal relationships when working with four components.

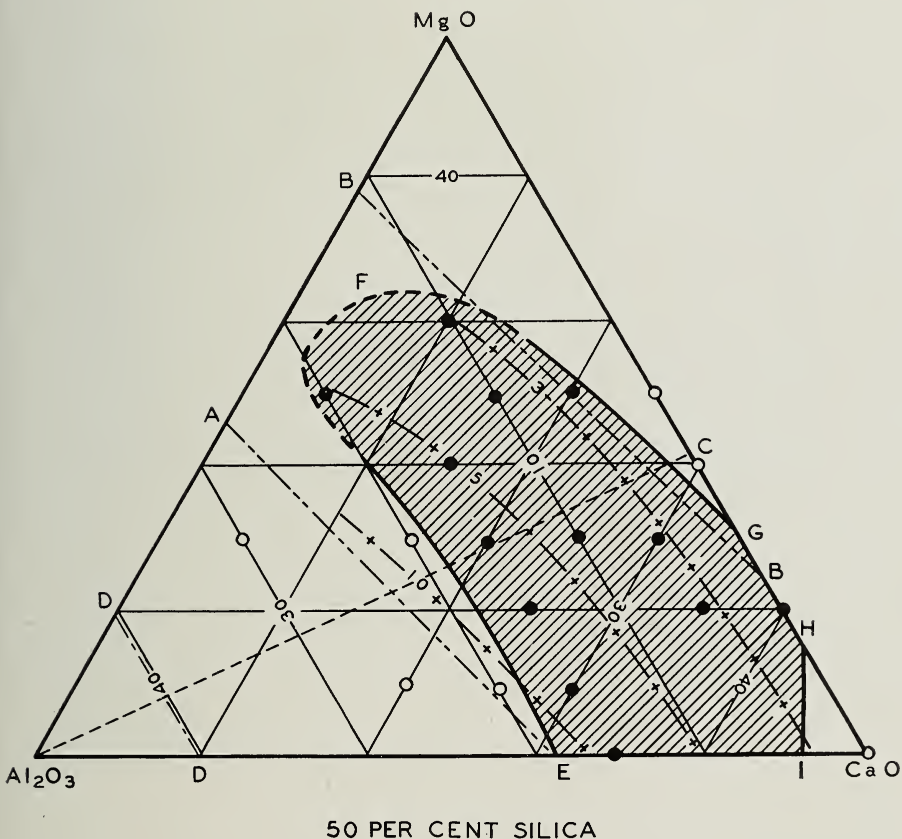
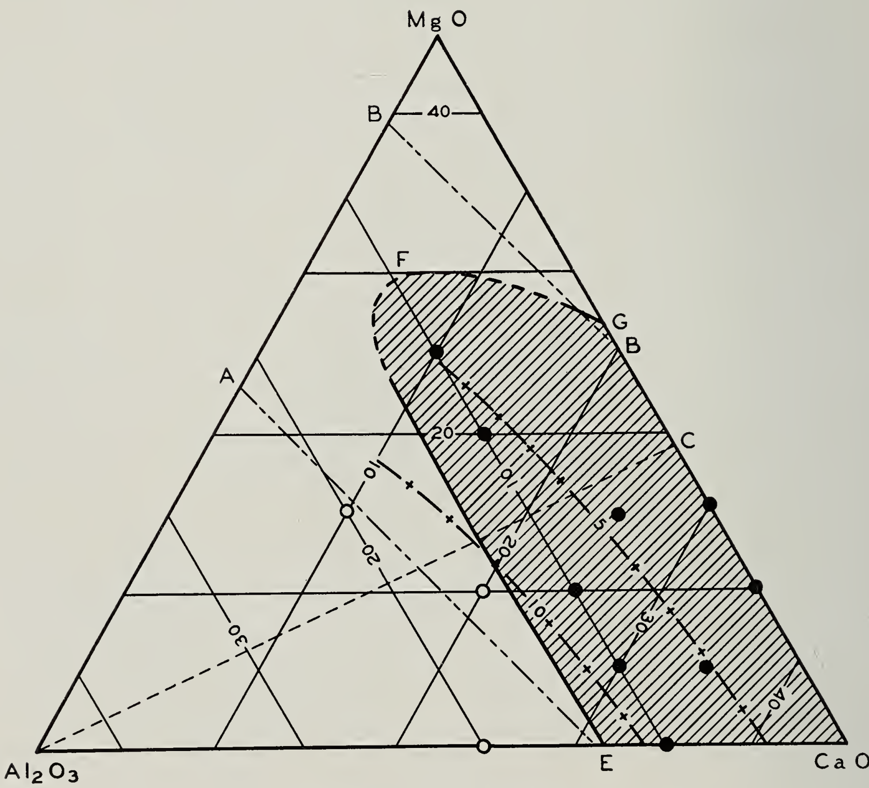


Fig. 25. Diagram showing range of compositions suitable for rock wool production in the quaternary system at 50 per cent silica.

The cross-dash lines, designated by the numerals 2, 3, 5, and 10, are lines of equal fiber diameters. The numerals refer to the average fiber diameters expressed in microns. It is of interest to note that these lines parallel, in a general way, lines expressing the sum of the acid or the sum of the basic components of the four-component system. Thus, in figure 20, these lines are roughly parallel to the lines denoting the percentage of lime, magnesia being constant; in figure 21, to lines denoting the percentage of silica, alumina being constant; and in the remaining figures, to lines denoting the percentage of alumina, silica being constant.

In Appendix II a rapid test for the evaluation of woolrock is described. In place of submitting samples to chemical analysis, from which the ratio of number of gram molecules of acidic components to number of gram molecules of basic components can be calculated, the loss of weight of a small



55 PER CENT SILICA

FIG. 26. Diagram showing range of compositions suitable for rock wool production in the quaternary system at 55 per cent silica.

sample on calcination between 400°C. and 1000°C. is determined. A preliminary heating at 400°C. is required to remove moisture and any other volatile materials which may be present. This test is based on the fact that sedimentary rocks generally contain a molecule of carbon dioxide for each molecule of lime or magnesia, and a measurement of the amount of carbon dioxide evolved from a sample is, in reality, a measurement of the basicity of the sample.

The tentative selection of 20 and 30 per cent limits for carbon dioxide was fortunate. These limits were subsequently found to delimit the range of compositions suitable for rock wool production quite accurately. In figure 20 the dash-double-dot line *AA* describes a path passing through all compositions, which, calculated to a rock basis, would contain 20 per cent carbon

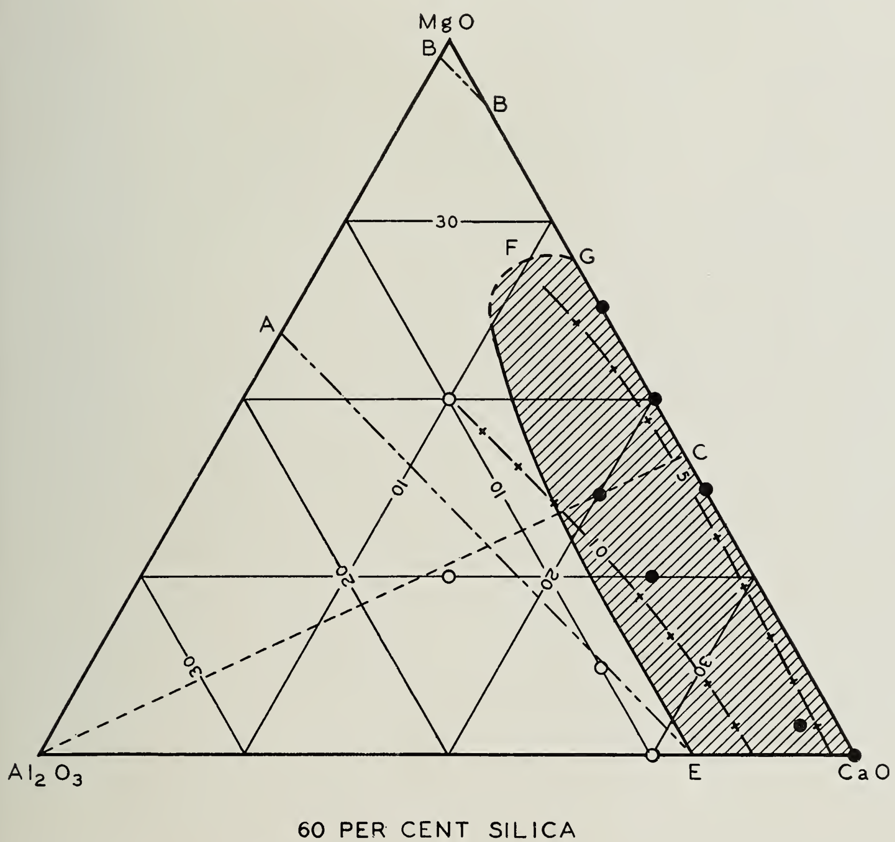


FIG. 27. Diagram showing range of compositions suitable for rock wool production in the quaternary system at 60 per cent silica.

dioxide. The line *BB* passes through all compositions which, on the same basis, would contain 30 per cent carbon dioxide. The area between these lines represents compositions which, converted to a rock basis, would contain between 20 and 30 per cent carbon dioxide. Similar lines are plotted on the remaining composition diagrams. It can be readily seen that, taking the kaolinite and dolomite ratio limitations into consideration, any naturally occurring mixture of shale, sandstone, and dolomite or limestone, which contains from 20 to 30 per cent carbon dioxide and which does not contain excessive amounts of impurities, is either suitable, from the standpoint of composition, for the production of rock wool, or can be made suitable by the addition of very small amounts of a rock containing a high percentage of the deficient component. This easily determined carbon dioxide content is there-

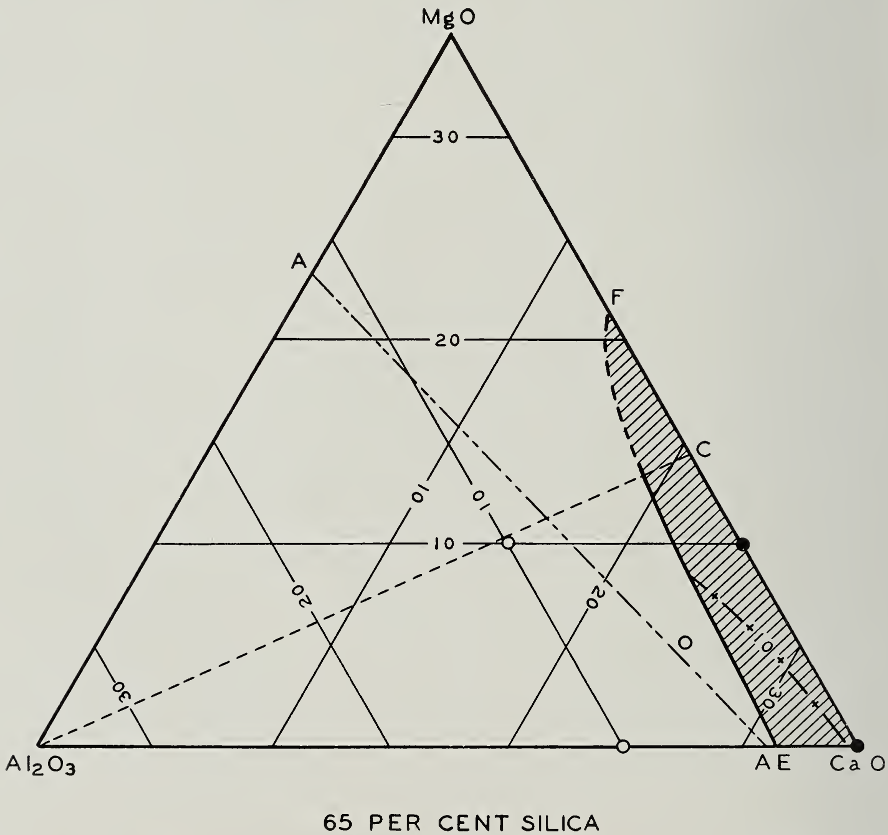


Fig. 28. Diagram showing range of compositions suitable for rock wool production in the quaternary system at 65 per cent silica.

fore a most useful criterion by which to judge the suitability of samples for rock wool production.

Figure 21 is similar to Fig. 20 and represents a portion of the lime-silica-magnesia ternary. The dolomite ratio is represented by the line extending from C to the silica apex. Despite the fact that Logan (*6*) reports that "alumina is an essential constituent of mineral wool," a number of very satisfactory alumina-free samples were prepared. Possibly efforts to make alumina-free wool in the past have been unsuccessful because the silica present was insufficient to compensate for the absence of alumina.

The remaining composition diagrams do not call for special comment. The fact that rock wool with satisfactory properties can be made from mixtures containing as high as 65 per cent silica may occasion some surprise, but this is readily accounted for by the low alumina content of such samples.

The composition diagrams, Figs. 20 to 28, can be of practical value in several ways. Whether or not a given sample of material offers promise for production of rock wool may be determined, first, by a determination of its

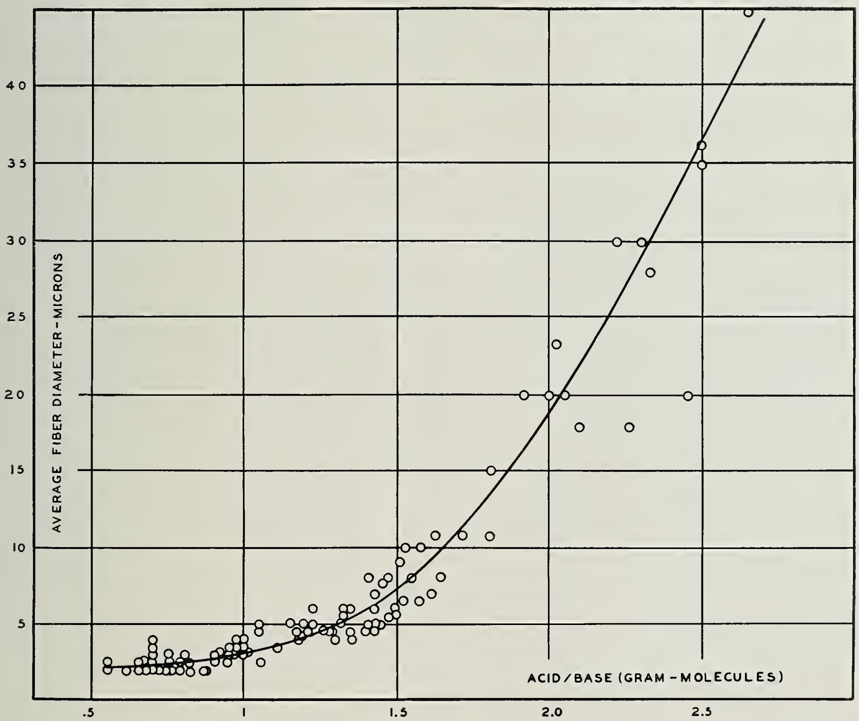


FIG. 29. Variation of fiber diameter with acid to base ratio.

carbon dioxide content, and second, by its location with respect to the areas of suitable composition in Figs. 22 to 28. Interpolation between the 5 per cent silica planes should be a simple yet reasonably accurate procedure. Remembering that these areas were all determined at one temperature, 1500°C., it is also possible to decide qualitatively what effect pouring at different temperatures should have on these areas. At lower temperatures the areas should contract and there should be an increase in the average fiber diameter of the wools. At higher temperatures an expansion of the shaded areas toward compositions high in silica and alumina and a possible shifting away from the areas producing fine wools would be expected. Finally, these diagrams show how to vary the composition to correct certain conditions which may be encountered in blowing. A practical use of them has been demonstrated in Chapter VI where the amounts of fluxing materials required to be added to rocks which lie outside the suitable limits of composition have been calculated.

Another way of showing the variation of fiber diameter with composition is given in figure 29. Composition is expressed in terms of the molecular acid-to-base ratio.

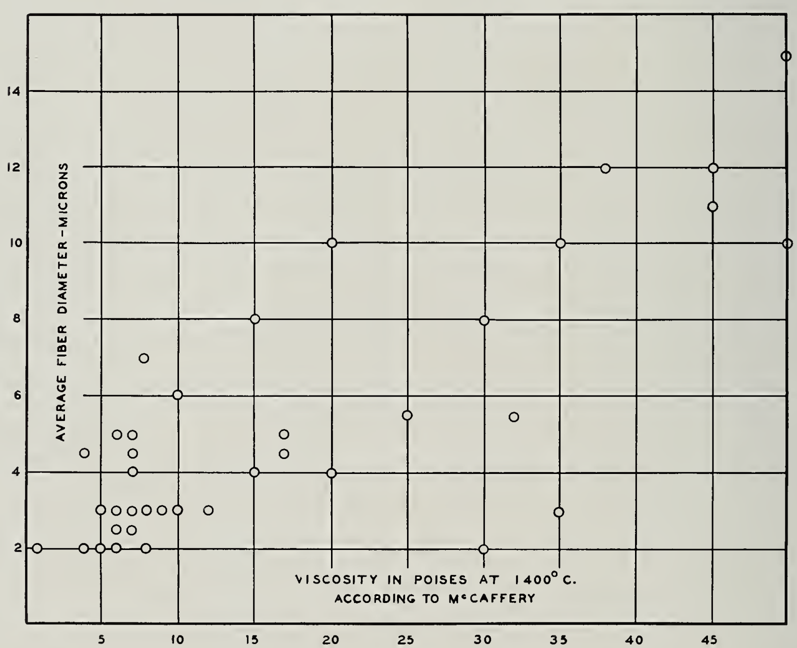


Fig. 30. Variation of fiber diameter with viscosity at 1400° C.

As might be expected, highly viscous melts yield coarse fibered wools. McCaffery (*32*) has measured the viscosity of a number of four-component blast furnace slags and presented his results in a series of composition-viscosity diagrams which cover a portion of the composition range investigated for rock wool production. Sample No. 56, for example, exhibits a fiber diameter of 3 microns and might be classified as a typical rock wool. According to McCaffery, a material of this composition exhibits viscosities ranging from 10 to 3 poises between the temperatures of 1400° and 1600° C. In a like manner, Sample No. 41, with a fiber diameter of 15 microns, lies in a viscosity range of 50 to 12 poises, and Sample No. 8, fiber diameter 2 microns, in a viscosity range of 4 to 1 poises. The viscosities of 49 samples listed in Table 24 can be determined from McCaffery's diagrams. Values for the viscosities of these samples at 1400°C. are plotted against fiber diameters in Fig. 30. Other than a trend to higher fiber diameters at higher viscosities, no relationship is apparent. This is not surprising, considering that surface tension and the manner in which both viscosity and surface tension vary with temperature are additional determining factors with regard to fiber diameters.

TABLE 23—*Comparison of "batch" compositions with analyses of synthetic rock wools*

Sample No.	"Batch" compositions (*Per cent*)				Analyses (*Per cent*)			
	SiO_2	Al_2O_3	MgO	CaO	SiO_2	Al_2O_3	MgO	CaO
5	65	0	10	25	63.11	1.12	10.10	25.50
7	45	0	0	55	44.90	0.41	1.59	52.89
8	45	0	10	45	44.87	0.26	10.46	44.00
11	50	0	25	25	48.49	0.05	24.90	26.36
23	55	0	10	35	53.63	0.13	11.50	34.88
99	40	20	30	10	40.28	19.50	30.10	10.12
100	40	30	25	5	40.47	27.83	25.78	5.77
105	55	10	25	10	54.39	9.46	26.66	10.32

TABLE 24—*Composition and fiber diameter of synthetic rock wools*

Synthetic mixture No.	SiO_2 *Per cent*	Al_2O_3 *Per cent*	CaO *Per cent*	MgO *Per cent*	Average fiber diameter (*microns*)
1	60	0	25	15	5
2	50	0	30	20	2.5
3	60	0	40	0	4.5
4	50	0	40	10	2
5	65	0	25	10	6.5
6	50	0	50	0	2.5
7	45	0	55	0	2.5
8	45	0	45	10	2
9	40	0	40	20	2
10	45	0	30	25	2.5
11	50	0	25	25	2.5
12	55	0	30	15	3
13	60	0	20	20	4
14	70	0	20	10	....
16	70	0	30	0	....
17	65	0	35	0	11
18	60	0	15	25	6
20	45	0	35	20	2
21	40	0	50	10	....
22	40	0	60	0	....
23	55	0	35	10	2.5
28	50	0	20	30	2.5
32	60	10	30	0	20
33	65	10	25	0	45
34	55	20	25	0	35
35	45	30	25	0	28
36	35	30	35	0	8
37	30	20	50	0	2
39	55	10	35	0	10
40	50	15	35	0	10
41	45	25	30	0	15
42	45	20	35	0	5.5
43	45	15	40	0	6
44	40	20	40	0	4
45	35	20	45	0	3

TABLE 24—Continued

Synthetic mixture No.	SiO_2 *Per cent*	Al_2O_3 *Per cent*	CaO *Per cent*	MgO *Per cent*	Average fiber diameter (*microns*)
46	30	10	60	0	....
47	40	10	20	30	2
48	40	20	15	25	3.5
49	40	30	15	15	5
50	40	35	20	5	18
51	40	20	25	15	5
52	40	10	30	20	2
53	40	5	30	25	2
54	40	5	50	5	3.5
55	40	5	40	15	2
56	40	15	35	10	3
57	40	15	25	20	2
58	40	20	35	5	5
59	50	25	20	5	18
60	50	20	15	15	7
61	50	15	15	20	4.5
62	50	10	15	25	4.5
63	50	5	20	25	2.5
64	50	5	30	15	4
65	50	5	35	10	4
66	50	15	30	5	6
67	50	20	25	5	11
68	50	15	20	15	6
69	50	10	25	15	3
70	50	15	25	10	5
71	55	15	20	10	10
72	55	10	15	20	6
73	55	5	25	15	4.5
74	55	10	25	10	8
75	55	10	30	5	8
76	55	5	35	5	4
77	60	2.5	35	2.5	5.5
78	60	10	25	5	20
79	60	5	25	10	9
80	60	5	20	15	5

Table 24—Concluded

Synthetic mixture No.	SiO_2 *Per cent*	Al_2O_3 *Per cent*	CaO *Per cent*	MgO *Per cent*	Average fiber diameter (*microns*)
81	35	15	25	25	2.5
82	35	30	20	15	5
83	35	30	30	5	5.5
84	35	20	40	5	3
85	35	10	50	5	2.5
86	35	5	45	15	2.5
87	35	10	35	20	2
88	35	20	30	15	3
89	65	10	15	10	30
90	65	5	25	5	20
91	45	20	25	10	4.5
92	45	10	25	20	2.5
93	45	5	25	25	2
94	45	5	35	15	2
95	45	5	45	5	3
96	45	15	35	5	4.5
97	45	10	30	15	3
98	40	30	0	30	4.5
99	40	20	10	30	3.5
100	40	30	5	25	4
101	40	30	10	20	5
102	50	10	10	30	3
103	50	20	5	25	8
104	50	30	5	15	20
105	55	10	10	25	4.5
106	55	20	10	15	23
107	60	10	10	20	11
108	60	15	15	10	30

Part IV

MINERAL ECONOMICS

By Walter H. Voskuil, Ph.D.

CHAPTER VIII.—THE ECONOMIC BASIS OF A ROCK WOOL INDUSTRY

INTRODUCTION

The ultimate success of a commercial rock wool industry depends upon the production and delivery of desirable rock wool to the market at a cost lower than materials coming from competing districts and below a price that will turn the customer to a competing product made from other materials. The insulation market is highly competitive and every item of cost that enters into the production from the assembly of the raw materials, their processing, and the transportation and distribution costs must be carefully scrutinized and calculated with the view of selecting a site or sites for a producing plant which will be in a position to deliver the product to an adequate consuming area with the lowest aggregate cost.

An analysis of the economic possibilities of rock wool manufacture in Illinois must, therefore, encompass a study of markets, of transportation facilities, and of the conditions of production in each area or group of areas in which favorable deposits are known to exist.

FUNCTION OF INSULATING MATERIALS

The function of insulating materials may be described as the reduction of undesired heat transfers. It is of greatest significance in the escape of heat from buildings, heating plants, boilers, etc., but is also of importance in preventing the entry of solar heat into buildings and dwellings. Rock wool has a multitude of uses in industrial processes, in manufactured goods, and in construction. Almost every publication on rock wool lists new uses for the material. The following compilation is merely suggestive:

(1) *As heat insulation for*

- a) Pipes: To prevent freezing of house and underground pipes, and to prevent loss of heat from pipes carrying steam, molten sulphur, hot oil, etc.
- b) Ovens, furnaces, and stoves, including steam boilers, fractionating columns, towers, annealing, baking, and enameling ovens, retorts, metallurgical and chemical furnaces.

c) Refrigerators, ice boxes, water coolers, and refrigerator cars.

d) Building walls, floors, and ceilings in the form of granulated wool, rock wool blankets, rock cork, and rock felt.

(2) For sound control:

Acoustic tiles, mats placed under carpets, in walls, and in partitions. It has been extensively used for insulating broadcasting studios.

(3) Miscellaneous:

Packing for acid carboys, filter mediums for corrosive fluids, air filter in hot-air heating, as a component of insulating cement, for prevention of entrance of vermin, fire prevention, constituent of polishing wheels, lining between planking and metal sheathing of ships, printers' blankets, etc.

THE RELATION OF ROCK WOOL TO BUILDING INSULATION

The purpose of house and building insulation is to reduce the escape of heat from the interior during the cold seasons and the entry of heat in the summer season. Consequently its market outlet possibilities extend over the entire country. The economic justification of building insulation is a saving in the annual fuel bill as well as an increase in the comfort of the home. The value of insulation in effecting fuel savings is indicated by data compiled by the U. S. Bureau of Standards (*33*):

	Fuel Saving *Per cent*
No insulation, weather stripped	15–20
Same, double windows	25–30
(a) ½-inch insulation, not weather stripped	20–30
(b) ½-inch insulation, weather stripped	40
(c) ½-inch insulation, with double window	50
(d) 1-inch insulation, not weather stripped	30–40
1-inch insulation, weather stripped	50
1-inch insulation, with double window	60

The use of house insulation raises certain problems which must be given careful consideration if its utilization is to be effective and the investment is to be economically justified. Effective heat conservation is a result of both good construction and proper use of insulating materials. The avenues of heat escape are many and varied and each must be closed by use of the proper method or material. The principal avenue of heat escape is through the ceiling of the upper rooms and the roof. Second in importance is the dissipation of heat through windows, both by reason of the high radiating properties of glass and also, very frequently, by reason of ill-fitting window frames. These two avenues probably account for most of the unnecessary heat losses.

TABLE 25—*Number of owned non-farm homes, by valuation, in cities of 10,000 or more population (a)*

By Market Areas

Market districts	Under $1,500	$1,500-$2,999	$3,000-$4,999	$5,000-$7,499	$7,500-$9,999	$10,000 and over	Not reported	Total	Per cent
Chicago	2,332	11,604	41,978	89,563	73,370	125,452	4,938	349,237	35
Milwaukee	694	4,797	20,484	36,673	18,818	16,876	1,040	99,382	10
Green Bay	789	3,348	7,902	6,828	1,571	1,537	441	22,416	2.3
Northern Ill.- Central Wis.-Minn	1,255	4,934	11,991	14,440	5,677	6,792	495	45,584	4.6
Twin Cities	2,624	11,510	31,732	36,140	9,734	10,859	793	103,392	10.4
Duluth	2,530	4,430	6,359	6,633	1,712	1,894	93	23,651	2.4
Davenport	2,680	8,333	16,276	15,206	4,146	4,214	563	51,418	5.2
Burlington	2,127	4,265	5,548	3,849	1,182	1,297	171	18,439	1.8
Des Moines	2,595	5,509	8,933	7,496	2,236	2,317	193	29,279	2.9
North Central Illinois	1,515	5,425	10,358	9,545	3,222	3,512	441	34,018	3.4
Central Illinois	1,907	6,401	10,372	9,288	2,904	3,985	547	35,404	3.6
St. Louis	5,555	14,884	27,265	29,170	14,736	21,516	1,541	114,667	11.5
Western Missouri	5,183	11,649	19,529	17,710	5,696	8,376	804	68,947	6.9
Total	31,786	97,089	218,727	282,541	145,004	208,627	12,060	995,834	
Per cent	3.2	9.7	22.0	28.4	14.5	21.0	1.2	....	100

(*a*) U. S. Bureau of the Census.

TABLE 26—*Number of rented non-farm homes, by monthly rental, in cities of 10,000 or more population (a)*

By Market Areas

Market districts	Under $15	$15-$29	$30-$49	$50-$99	$100 and over	Not reported	Total
Chicago	24,019	125,768	164,469	271,213	35,473	12,149	633,091
Milwaukee	3,597	31,103	43,699	24,917	1,952	866	106,134
Green Bay	1,472	6,038	3,298	920	38	304	12,070
Northern Ill.-Central Wis.-Minn.	2,118	12,545	14,117	6,197	248	444	35,669
Twin Cities	6,964	38,805	39,910	18,002	1,141	1,351	106,173
Duluth	3,498	9,203	5,087	1,655	109	135	19,687
Davenport	4,578	19,670	15,551	3,923	104	549	44,375
Burlington	3,302	6,803	2,903	583	12	138	13,741
DesMoines	3,491	10,197	9,162	3,602	188	387	27,027
North Central Illinois	2,721	10,262	9,057	3,442	145	665	26,292
Central Illinois	3,426	11,079	8,390	3,716	182	611	27,404
St. Louis	25,050	67,965	58,675	29,849	4,005	2,185	187,729
Western Missouri	14,530	33,286	28,593	11,682	1,052	2,025	91,168
Totals	98,766	382,724	402,911	379,701	44,649	21,809	1,330,560

(*a*) U. S. Bureau of the Census.

TABLE 27—*Number and distribution by value or rental of non-farm homes in cities of the Chicago district (a)*

(By value)

Chicago area	Under $1,500	$1,500-$2,999	$3,000-$4,999	$5,000-$7,499	$7,500-$9,999	$10,000 and over	Not reported	Total
Aurora	108	300	1,498	3,125	1,235	1,256	80	7,602
Berwyn	10	22	255	1,396	3,092	3,206	62	8,043
Blue Island	9	76	384	794	427	523	60	2,273
Brookfield	4	23	116	655	790	321	17	1,926
Calumet City	23	93	358	578	222	192	110	1,576
Chicago Heights	33	209	647	830	355	526	44	2,644
Cicero	23	133	809	2,499	2,506	2,803	106	8,879
Elgin	93	336	1,398	2,262	838	713	58	5,698
Elmhurst	3	12	79	466	864	1,251	46	2,721
Evanston	8	25	158	455	553	4,982	69	6,250
Forest Park	4	9	100	583	569	604	30	1,899
Harvey	32	131	457	801	354	393	12	2,180
Highland Park	2	11	47	143	175	1,510	27	1,915
Joliet	42	311	1,069	1,710	834	1,404	64	5,434
Kankakee	51	207	828	1,054	360	437	65	3,002
Maywood	7	18	150	800	1,525	1,419	75	3,994
Melrose Park	7	24	179	514	239	175	34	1,172
Oak Park	6	10	72	627	1,743	6,690	131	9,279
Park Ridge	2	3	24	135	295	1,681	9	2,149
Waukegan	17	131	441	1,423	898	1,262	44	4,216
Wilmette	1	3	19	82	108	2,497	29	2,739
Winnetka	......	2	3	29	75	1,848	9	1,966
Totals	485	2,089	9,091	20,961	18,057	35,693	1,181	87,557

(*a*) U. S. Bureau of the Census.

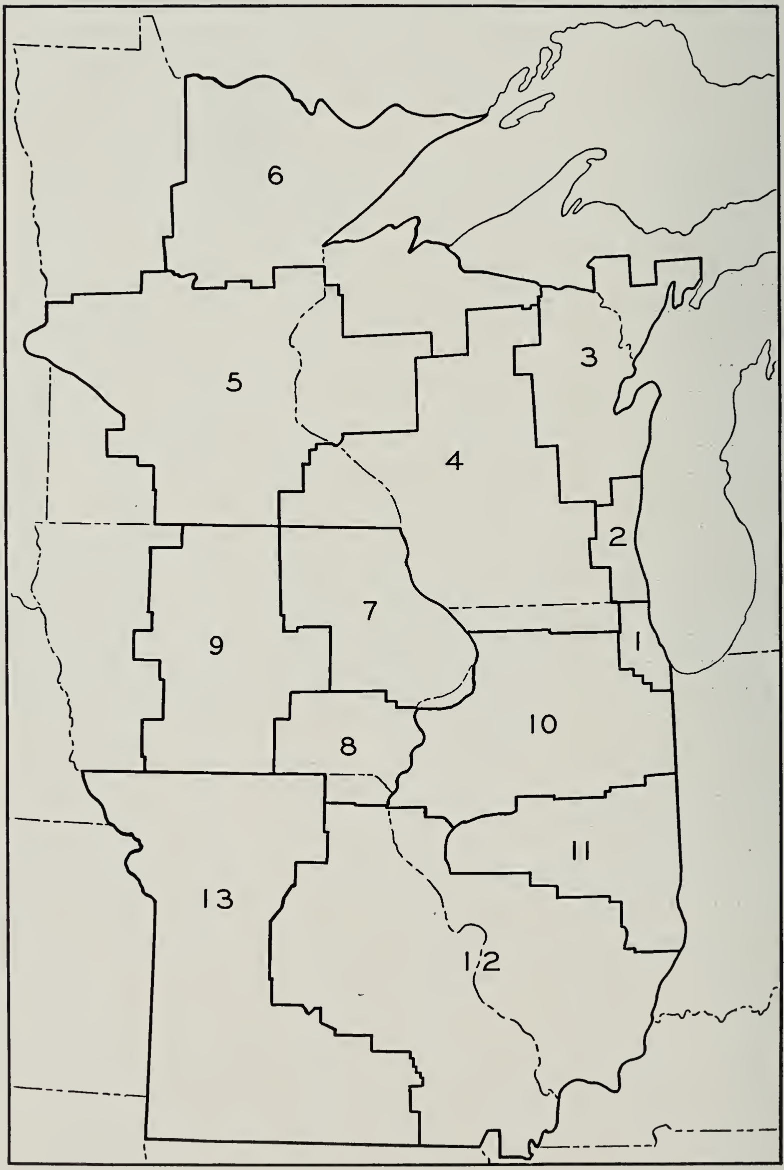


FIG. 31. Illinois market area showing potential markets for Illinois rock wool (see Tables 25-30).

1. Chicago
2. Eastern Wisconsin
3. Green Bay
4. N. Illinois-Central Wisconsin-Winona, Minnesota
5. St. Paul-Minneapolis
6. Duluth
7. Davenport
8. Burlington
9. Des Moines
10. N. Central Illinois
11. Central Illinois
12. St. Louis-Southern Illinois
13. Western Missouri

Table 27—Concluded

(By rental)

Chicago area	Under $15	$15-$29	$30-$49	$50-$99	$100 and over	Not reported	Total
Aurora	155	1,232	1,980	689	30	100	4,186
Berwyn	21	288	1,009	2,605	48	49	4,020
Blue Island	44	473	717	375	6	20	1,635
Brookfield	8	67	236	238	4	13	566
Calumet City	51	313	421	312	4	60	1,161
Chicago Heights	185	1,011	582	448	8	57	2,291
Cicero	181	1,857	2,759	2,207	80	119	7,203
Elgin	81	891	1,694	530	19	37	3,252
Elmhurst	9	64	282	448	14	22	839
Evanston	53	422	1,288	5,172	2,904	141	9,980
Forest Park	14	267	795	767	19	19	1,881
Harvey	53	452	892	426	12	10	1,845
Highland Park	7	66	248	405	174	8	908
Joliet	385	748	426	135	7	31	1,732
Kankakee	138	988	825	207	6	48	2,212
Maywood	13	219	847	1,219	7	88	2,393
Melrose Park	29	406	468	113	3	99	1,118
Oak Park	16	85	654	5,604	1,055	187	7,601
Park Ridge	5	26	100	352	32	7	522
Waukegan	81	818	1,753	1,317	69	29	4,067
Wilmette	9	68	165	321	258	16	837
Winnetka	1	8	72	339	244	9	673
Totals	1,539	10,769	18,213	24,229	5,003	1,169	60,922

Insulation of a house, therefore, to be effective must not be confined to the selection and installation of insulating materials in the walls, ceilings, and roof; it must also include care in the construction of all parts of the house, and in the reduction of radiation from windows. If this is not done, the effect of installing insulating materials in the frame of the house may be nullified by the escape of heat due to poor construction.

MARKET FOR INSULATING MATERIAL IN THE DWELLING HOUSE FIELD

The insulation of dwelling houses is becoming more prevalent as the economic value and comfort of heat conservation and air conditioning is becoming more widely recognized. The potential demand for rock wool in the housing field is somewhat difficult to estimate quantitatively due to the complex nature of the market. Insulation in new construction is practically accepted and this market may be expected to grow in proportion to the rate of revival of house construction. Existing structures, also, can be improved by insulation and probably will offer the more immediate market outlet. The extent of this market cannot, however, be estimated by a mere count of the number of existing structures. Market possibilities naturally vary with the value of the house, whether it is occupied by the owner or is tenanted, whether it is urban or rural, etc. Moreover, market areas differ in potentialities because of the unequal distribution of population and concentration in large urban centers. For purposes of analysis, the Illinois house insulation market is divided into thirteen districts, within each of which the number of dwellings, classified according to value, whether owned or rented, is tabulated below. The districts so delimited and their boundaries are shown on the accompanying map (Fig. 31).

1. Chicago
2. Eastern Wisconsin
3. Green Bay
4. Northern Illinois–Central Wisconsin–Winona, Minnesota
5. St. Paul–Minneapolis
6. Duluth
7. Davenport
8. Burlington
9. DesMoines
10. North Central Illinois
11. Central Illinoise
12. St. Louis–Southern Illinois
13. Western Missouri

For each of these districts in Tables 25 and 26 is given the number of non-farm homes, owned or rented, in cities of 10,000 population or over. This comprises the most probable market for insulating materials. The cities in this group have shown a larger percentage in population growth than smaller communities, and consequently, are likely to show greater building activity. Farm homes are not included in this tabulation although the need of insulation on farms, not only in the farm home but also in buildings used for housing live stock, exists, and as the economic value of insulation becomes apparent, this market should be given further study.

For each of these districts also, the non-farm homes are classified according to value, if owned, or monthly rental, if occupied by tenants. The values, or rentals, into which they are grouped, are as follows:

Value of homes owned	Monthly rental
Under $1500	Under $15
1500 – 2999	$15 to $29
3000 – 4999	$30 to $49
5000 – 7499	$50 to $99
7500 – 9999	$100 and over
10000 and over	

The values given are those gathered by the Bureau of the Census and represent home values as of April 1, 1930. They can be used as a guide in estimating the percentage of total number of houses that are potential markets for rock wool. Obviously, houses valued at less than $1500 would be

TABLE 28—*Number and distribution of owned non-farm homes, by value, in principal cities (a)*

	Under $1,000	$1,000-$1,499	$1,500-$1,999	$2,000-$2,999	$3,000-$4,999	$5,000-$7,499	$7,500-$9,999	$10,000-$14,999	$15,000-$19,999	Over $20,000	Unclassified	Total
Chicago	428	1,419	1,736	7,779	32,887	68,602	55,313	53,401	18,646	17,712	3,757	261,680
St. Louis	414	998	1,311	4,395	15,175	18,800	10,910	9,329	2,997	2,158	675	67,162
Milwaukee	113	296	464	2,839	13,913	21,591	11,245	6,382	1,668	1,515	643	60,669
Minneapolis	264	614	999	3,625	15,837	20,242	5,763	3,916	1,305	1,403	403	54,371
Kansas City	294	663	945	3,406	12,061	13,315	4,481	3,929	1,219	1,573	428	42,314
St. Paul	426	660	970	3,511	10,907	11,621	2,828	1,892	607	604	223	34,249
Peoria	160	206	392	1,279	3,625	3,877	1,553	1,192	347	337	139	13,107
Des Moines	825	1,024	1,094	2,603	5,773	4,666	1,447	938	311	340	130	19,151
Duluth	206	286	345	1,101	3,605	4,735	1,248	851	267	323	57	13,024
Total	3,130	6,166	8,256	30,538	113,783	167,449	94,788	81,830	27,367	25,965	6,455	565,727

(*a*) U. S. Bureau of the Census.

TABLE 29—*Number and distribution of rented non-farm homes, by rental, in principal cities (a)*

	Under $10	$10-$14	$15-$19	$20-$29	$30-$49	$50-$74	$75-$99	$100-$149	$150-$199	Over $200	Not reported	Total
Chicago	5,100	17,380	33,805	81,194	146,256	186,484	60,500	20,730	4,820	4,920	10,980	572,169
St. Louis	3,740	11,305	17,603	32,174	49,391	20,001	4,909	2,274	641	370	1,434	143,842
Milwaukee	531	2,192	5,301	17,258	32,919	17,025	3,187	1,144	269	168	633	80,627
Minneapolis	553	2,441	5,705	14,635	24,023	10,260	1,559	595	140	95	971	60,977
Kansas City	1,677	4,648	6,019	14,763	23,600	8,446	1,839	736	137	103	1,440	63,408
St. Paul	547	2,166	3,954	8,488	12,229	4,300	560	200	43	17	285	32,789
Peoria	274	791	1,504	3,184	4,387	1,889	356	91	17	6	311	12,810
Des Moines	723	1,801	2,201	4,410	5,726	2,324	467	135	32	4	294	18,117
Duluth	277	938	1,565	3,346	3,097	1,042	180	67	8	5	55	10,580
Total	13,422	43,662	77,657	179,452	301,628	251,771	73,557	25,972	6,107	5,688	16,403	995,326

(*a*) U. S. Bureau of the Census.

TABLE 30—*Number and distribution by value, or rental, of non-farm homes in the States of Illinois, Wisconsin, Minnesota, Iowa and Missouri, and in cities of more than 100,000 population (a)*

Owned-non-farm homes, by valuation

State	Under $1,000	$1,000-$1,499	$1,500-$1,999	$2,000-$2,999	$3,000-$4,999	$5,000-$7,499	$7,500-$9,999	$10,000-$14,999	$15,000-$19,999	Over $20,000	Unclassified	Total
Illinois	37,033	36,146	32,568	69,369	141,756	170,542	100,887	94,847	33,963	34,929	13,506	765,546
Wisconsin	11,123	12,403	14,017	35,526	80,699	78,185	29,422	18,264	5,312	4,891	6,615	296,457
Minnesota	11,164	11,193	13,171	31,827	68,402	58,317	14,063	9,464	2,883	2,914	3,938	227,336
Iowa	16,332	18,059	18,750	38,906	67,430	47,137	11,428	7,044	1,879	1,462	5,082	233,509
Missouri	28,779	22,683	20,328	39,112	68,660	57,328	22,992	19,836	6,906	7,272	6,197	300,093
Total	104,431	100,484	98,834	214,740	426,947	411,509	178,792	149,455	50,943	51,468	35,338	1,822,941

Rented non-farm homes, by rental

State	Under $10	$10-$14	$15-$19	$20-$29	$30-$49	$50-$74	$75-$99	$100-$149	$150-$199	Over $200	Not reported	Total
Illinois	44,905	64,312	77,373	149,311	220,918	221,945	69,898	25,296	6,058	5,777	20,826	906,619
Wisconsin	13,961	20,820	26,156	52,161	66,116	26,971	5,007	1,787	382	250	4,448	218,059
Minnesota	11,855	20,327	26,451	45,275	53,113	18,118	2,600	1,010	231	152	3,725	182,857
Iowa	16,669	29,011	29,701	44,415	38,521	8,649	1,128	320	66	30	3,985	172,445
Missouri	44,665	48,532	45,842	71,973	90,140	34,334	8,814	4,064	986	566	7,894	357,810
Total	132,055	183,002	205,523	363,135	468,808	310,017	87,447	32,477	7,723	6,775	40,878	1,837,790

(*a*) U. S. Bureau of the Census.

poor prospects for insulation; this low value does not warrant substantial expenditures for improvements. Probably extensive remodelling would be necessary if insulating materials were to be of any value in preventing heat escape. This group may also include a high proportion of old houses whose economic life is nearly past. This reasoning may also apply to houses in the next higher valuation group, i. e., $2000 to $2999. These two groups together constitute 13 per cent of the total number of owned non-farm homes. The market must be sought in the remaining 87 per cent, the valuation of which is sufficiently high to make insulation economically feasible.

Because of the diversity of values in the several cities comprising the Chicago district, Table 27 has been prepared showing the number and distribution of buildings, by value or rental, in each of the cities of this district.

Tables 28, 29, and 30 give the distribution of homes by value, or rental, in the larger cities of the area, and total figures for the five states comprising the market area under discussion.

In the non-farm group of houses occupied by tenants, the market for insulation is probably less promising than in homes occupied by the owner. The incentive to improve a building becomes effective only if a higher rental results from it, and until evidence of such returns becomes apparent, it is unlikely that landlords will undertake to improve their properties in this manner.

GEOGRAPHIC DISTRIBUTION OF THE MARKET

Each of the above mentioned districts comprises an area tributary to a principal distributing or market center. Two-thirds of the potential market, as indicated by the number of homes, is in the Chicago, St. Louis, St. Paul-Minneapolis and Milwaukee market areas.

Relation of the Transportation System to the Market Areas

The railroad transportation system is well equipped to distribute rock wool from potential producing points to the several market districts. For the eastern, northern, and northwestern market districts, the focal point in distribution is the Chicago switching district and the Outer Belt Line. The Chicago terminal district is contained within the boundary set by the so-called Outer Belt Line—the Elgin, Joliet and Eastern Railway—which extends from Waukegan, Illinois, on the north, through Joliet and Eola on the west, and to Porter, Indiana, on the east.

Radiating from the Chicago terminal district are trunk line steam railway systems having trackages ranging from 650 to 13,000 miles in length, two steam lines each less than 30 miles long, one electrically operated freight and passenger line, and three electric interurban passenger lines. Through the Outer Belt Line, switching connections are made with all railroads entering the Chicago terminal district.

Railroads

Some of the principal railroads which serve the Chicago, Wisconsin, northern Iowa and Minnesota market districts are as follows:

1. Chicago: All railroads from the north and west enter this market.
2. Wisconsin lake shore counties: Chicago and Northwestern; Chicago, Milwaukee, St. Paul and Pacific; Wisconsin Central.
3. Other Wisconsin and Northern Illinois markets: Chicago and Northwestern; Chicago, Burlington and Quincy; Chicago, Milwaukee, St. Paul and Pacific; Chicago Great Western; Illinois Central; Chicago, Rock Island and Pacific.

The St. Louis area is served by several railroads from the east, north, and south converging upon the metropolitan district. Both East St. Louis and St. Louis are connected to all railroads through the Terminal Railroad. River transportation is available by means of a floating terminal which can be used through a river stage variation of 40 feet.

PLANT LOCATION

The insulating materials market is a highly competitive one and a plant location must be selected which will result in the lowest cost of assembling raw materials and fuel and delivering the finished product to the markets. The elements that comprise the factor of total cost may be enumerated as follows:

(1) Size, location, and probable growth of market.
(2) Cost of site.
(3) Cost of obtaining suitable fuel at the factory site.
(4) Cost of quarrying and delivering raw materials to the factory site.
(5) Cost of manufacturing.
(6) Transportation costs on finished products, from proposed point of production to markets.

It should be noted that the determining factor in selecting the plant site is the aggregate annual cost of the items enumerated above rather than the cost of one item.

Obviously a woolrock deposit of suitable extent and low quarrying costs located near a large market center would be most favorable for commercial exploitation or development. The market demand for rock wool, in terms of tonnage, is not large enough to warrant the building of railroad spurs or other special transportation lines to a deposit which in itself is of suitable composition and extent, solely for this traffic. However, the geological and site characteristics of deposits near market centers and the transportation facilities may be of a nature as to necessitate high development and quarrying costs due to price of the site, depth of overburden, character of the rock, and transportation costs from factory site to railroad siding.

The ideal plant location would be near the large markets of Chicago or St. Louis and on railroads which would permit direct connections to nearby cities in Wisconsin, Minnesota, Iowa, or interior Illinois. This ideal location must be modified, however, by a consideration of available deposits. Nature has not necessarily placed these near the large markets. With the general picture of the potential market areas in mind, investigation of commercially feasible sites should begin with an examination of the raw material factors.

Fuel

In addition to the woolrock itself fuel is the most important raw material that is required in the production process. Coke is the form of fuel generally used. According to Thoenen (*3*) from 2 to 5 tons of rock are melted for each ton of coke required. This fuel is available from several plants in Chicago and from outlying plants in the Chicago district at Joliet, South Chicago, Waukegan, Gary, Indiana, and Indiana Harbor, Indiana. In the St. Louis district, coke is manufactured at Granite City, Illinois, and at St. Louis, Missouri.

Woolrock Deposits

Previous chapters of this report describe in some detail deposits whose geological characteristics have been examined, and samples of which have been investigated for wool making purposes. These deposits probably comprise only a part of the State's resources. They have been selected from representative areas throughout the State. A study of the description of these deposits will yield preliminary information on their probable extent, thickness, depth of overburden, and other items upon which a tentative estimate of the commercial value may be made. More detailed information concerning specific deposits, which preliminary examination indicated as promising, should be obtained before making a definite choice.

Freight Rates

The principal variable in the cost of delivering the manufactured product to the market is the freight rate. The relation of the freight rate structure to the delivered cost of rock wool products is complicated because of the differences in size of potential markets within reach of a producing site, and the possibility of using rail, truck, and possibly water transportation or a combination of these services. The various freight rate combinations should be determined to each of several important market areas as a preliminary step to evaluating total cost items.

The studies of woolrock resources have been restricted largely to three general districts, the Chicago, East St. Louis and Northwestern Illinois districts, within which deposits are considered to be favorably located for commercial exploitation. However, a few deposits in other regions have also been investigated. The various areas within which woolrock or sub-woolrock have been found are tentatively considered as "economically favorable" areas if they occur within the three major districts mentioned above and "less economically favorable" areas if outside these districts. The areas studied are classified below.

Economically favorable areas

CHICAGO DISTRICT	ST. LOUIS DISTRICT	NORTHWESTERN ILLINOIS
Blue Island	DuQuoin	JoDaviess–Stephenson Co.
Divine	East St. Louis	Milan
Elgin–Aurora	Freeburg	
Kankakee	Gale–Grand Tower	
LaSalle	Valmeyer	
Lemont		
Oregon		
Pontiac		
Thornton		
Utica		

Less economically favorable areas

Cooperstown	Mill Creek
Princeville	Peoria–Farmington

In the Chicago district, several deposits of woolrock or sub-woolrock have been located. All have direct railroad connections to the large Chicago market and connections with the Elgin, Joliet and Eastern Railway (Outer Belt Line) which puts these areas in connection with the markets of the outer Chicago district and the markets in eastern and southern Wisconsin. Coke is obtainable from the ovens in the Chicago district.

The deposits in the St. Louis area are also favored with convenient transportation facilities and a reasonably large market center. The DuQuoin deposits, for example, are 74 miles from St. Louis by direct rail haul, and also have direct rail connections with the cities of southern and central Illinois. The Gale-Grand Tower area is somewhat further removed but also has direct rail connections to St. Louis. Deposits of woolrock appear to be ample. Coke is available in the St. Louis market.

Deposits in northwestern Illinois are worthy of consideration as economically favorable areas for commercial development mainly on the basis of their access to several market centers in Wisconsin and Iowa, as well as

Chicago. Deposits containing woolrock or sub-woolrock have been located in JoDaviess and Stephenson counties on the Chicago Great Western and the Illinois Central railroads. The former is connected with the Chicago market on the east and the Iowa markets to the west. The Illinois Central is connected, either directly or by connecting railroads, with the market centers in Minnesota, Iowa, northern Illinois, southern Wisconsin, Chicago, and, through the Elgin, Joliet and Eastern, also with the markets of eastern Wisconsin.

The delivered price of coke will be somewhat higher than in the Chicago area.

SUMMARY

Rock wool is finding an increasing number of uses in construction, industry, and transportation. The most important outlet in the immediate future is in the insulation of new and old dwellings. The geographical position of the State of Illinois is peculiarly favorable for the location of a rock wool industry. Rail and waterway transportation routes serve as direct connections to the metropolitan areas of Chicago and St. Louis as well as other important market centers in Milwaukee, St. Paul, Minneapolis, Duluth, Davenport, Madison, and other cities. Two-thirds of the potential market, as indicated by the number of homes, is in the Chicago, St. Louis, St. Paul-Minneapolis, and Milwaukee markets.

Deposits of woolrock are found in widely distributed points throughout the State but not all are of equally potential economic value. Areas containing woolrock deposits have been provisionally classified as favorable economic areas and less favorable economic areas based on their distance from fuel supplies and markets. Within each of these areas are deposits whose geologic characteristics affect the cost or advisability of development. When this factor is taken in conjunction with the factors of fuel supply and distance from market, the differential between deposits in favorable and less favorable economic areas may disappear or even be reversed.

APPENDICES

By Charles F. Fryling

APPENDIX I

THE MANUFACTURE OF ROCK WOOL

A Summary of the Literature

Modern practice in rock wool manuacture apparently favors the use of unlined, water-jacketed steel kilns, 7½ feet in diameter and 16 feet high, with a capacity of 1000 pounds per hour. Coke is generally used for fuel and a forced draft is used (*6*). Details of various processes are given in Table 31. It will be observed that there is, with one exception, a remarkable uniformity in the published descriptions of the process. Some of the data presented, especially those of Thoenen (*3*), are representative of average practice in a number of plants. Whether the temperatures given are the highest attained in the kiln, or the blowing temperatures, cannot be determined from the literature.

A rather detailed description, together with a bibliography, of early manufacturing practices in the mineral wool and rock wool industries, was prepared by E. C. Eckel (*34*) in 1903.

The wasteful nature of the blowing process is pointed out by Lang (*1*). His method of decreasing the consumption of power in this process, namely by designing a better form of nozzle, has apparently been widely adopted. According to Thoenen, the best form and shape of the steam jet blower is kept secret. Generally, the arrangement is that of a trough into which the slag stream falls. A United States patent was issued to Koberle (7) for such an arrangement of steam jets in 1927. A nozzle, using a ring segment blast, has been patented in Germany (*22*).

The practice of oiling the wool by the introduction of some form of petroleum into the steam jet appears to be widely adopted. Its advantages are that it makes the wool coherent and free from dust. Patents were granted on this practice to Parkison (*8*) in 1910 and to Fay (*9*) in 1918.

The mineral wool is blown into collecting rooms, from which it is removed either by hand or by a belt conveyor. A few photographic illustrations of manufacturing and fabricating operations are given in references 2 and 10.

Thoenen (*3*) includes in his paper a history of rock wool development; a list of all producers; a description of mining operations, manufacturing practice, and various plants; and information on prices, markets, and production statistics. He states that the rock is quarried by the usual pit quarry method. Formerly (*2*) it was crushed to 2½ inch size, but since spalls and fines interfered with the action of the cupolas, the rock is now burned without crushing.

Guttmann (*4*) states that it is the practice of some German producers to blow slag wool as the slag comes from the blast furnace. The product does not compare favorably with that produced by a second heating.

TABLE 31—*Manufacturing practice in mineral wool production*

Reference	Lang (1)	Thoenen (2)	Thoenen (3)	Goudge (5)	Logan (6)
Location	California	Indiana	....	....	Indiana
Raw material used	copper slag	rock	rock or slag	rock	rock
Type of kiln	firebrick	steel	steel	steel unlined	steel
Dimensions of kiln	....	7 x 16′	7½ x 16′	4 - 6′ x 8 - 15′	7½ x 16′
Capacity lbs. per hr	1,000	1,000	1,000	900	1,000
Kiln blast	suction	pressure	pressure	pressure	pressure
Fuel	oil and briquets	....	coke	coke	coke
Fuel consumption per ton slag, in lbs	200	....	400-1500	330 av.= 570	400-1300
Wool blown with	air	steam	steam	steam or air	steam
Blowing pressure; lbs. per sq. in	75	100	80-100	80-100	85-100
Temperature degrees C	1,093	1,649	1538-1649	1538-1810	1371-2100
Temperature degrees F	2,000	3,000	2800-3000	2800-3300	2500-3800

APPENDIX II

ANALYTICAL PROCEDURE AND RESULTS OF RAPID CALCINATION TESTS

Rock analyses are expressed in terms of volatile constituents (CO_2, H_2O etc.,) and permanent oxides (SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO). Calcination, by driving off the volatile materials increases the percentages of the permanent oxides proportionally.

Studying the production and properties of rock wool naturally focuses attention on the calcined values, whereas the rock compositions are of more interest to the geologist or quarryman. Throughout the investigation, the following procedure was adopted to convert rock analyses to the calcined basis. If the sum of the rock constituents is 100 per cent or slightly over, the calcined analysis is calculated in the usual manner by dividing the percentage of each oxide by the sum of the percentages of permanent oxides. Fe_2O_3 and Al_2O_3 are frequently reported together as R_2O_3. Na_2O, K_2O, TiO_2, and other minor constituents are grouped together under miscellaneous oxides. If the sum of the rock constituents does not add to 100 per cent, it is assumed that certain materials, such as Na_2O and K_2O, have not been determined. In this case, the sum of the permanent oxides is arbitrarily increased by the difference between the total of the rock analysis and 100 per cent, and this difference is reported under miscellaneous. The same procedure is followed in considering the various compositions reported in the literature.

Standard Analytical Procedure

The procedure of Hillebrand and Lundell (*26*) was used for rocks containing more than one per cent of soda and potash. The silica was dehydrated twice with HCl and treated with HF. Lime was determined gravimetrically, ferric oxide volumetrically by titration with permanganate solution, and alumina was obtained by difference. MgO was determined by a double precipitation with microcosmic salt solution followed by ignition. Potash was determined as potassium chloroplatinate, and soda by difference after purification of the alkali chlorides. In the case of rocks, CO_2 was determined by liberation with HCl, absorption in KOH solution and subsequent weighing.

The procedure was simpler for samples which were free from soda and potash. The silica was dehydrated with perchloric acid, ignited and weighed. R_2O_3 was precipitated with NH_4OH, ignited and weighed; CaO was determined volumetrically by titration of calcium oxalate-sulphuric acid solution with potassium permanganate; and MgO by ignition of the magnesium ammonium phosphate precipitate. The results were reported to one decimal place. All analyses were made in duplicate.

The compositions of a number of commercial mineral wools which were analyzed in this laboratory, are given in Table 22 (p. 188). The first four samples are all of the same brand and show how the product may vary from time to time.

Determination of CO_2 Content by Calcination

To avoid the necessity of analyzing all the rock samples collected, the following method of estimating the combined alkaline earth content of the various samples was used. A one-gram sample of dried pulverized rock was weighed into a porcelain crucible. The crucible was then heated at 400° C. for one hour, cooled in a desiccator and weighed. This treatment eliminated moisture. The sample was then heated at 1000° C. for one hour, cooled, and weighed. The difference in weight between the latter two weighings closely approximates the CO_2 content of the sample. Rapidity was achieved by running as many as 20 samples simultaneously. The utility of the method depends upon the fact that the loss of weight on calcination between the temperatures of 400° C. and 1000° C. is roughly proportional to the lime and magnesia content of the sample.

The CO_2 content of the sedimentary rocks which occur in Illinois may vary from 0 per cent to 47.7 per cent, the calculated CO_2 content of pure dolomite. It is only necessary to set certain arbitrary limits within which experience has demonstrated the suitability of samples for rock wool production in order to make a preliminary evaluation of samples. The accuracy of this method was checked by comparison with the CO_2 calculated from the analytical values obtained for lime and magnesia in rocks. The agreement is not good for values below 15 per cent CO_2, but this does not invalidate the use of the method. A comparison of 30 analyses of samples containing more than 15 per cent CO_2 showed an average difference of 1.2 per cent between the values obtained by this method and the CO_2 values calculated from the lime and magnesia contents. One source of error which may be easily detected is the presence of coal in certain caprocks.

At the start of the investigation, tentative CO_2 limits of samples suitable for rock wool production were decided on the basis of calculations made from published analyses, (Table 32). Subsequently, CO_2 values were calculated from the analyses of a number of commercial samples (Table 33). The CO_2 values of those rocks which yielded wools when melted and blown or were shown by analyses to fall within the composition limits of woolrock, are given in Table 34, while values for samples of sub-woolrocks which require the addition of moderate quantities of fluxing material are listed in Table 35. The sample numbers under Table 32 correspond to those of Table 21 (p. 187); those under Table 33 with Table 22 (p. 188); the remainder are the sample numbers given to the rocks as they were collected in the field.

Twenty to thirty per cent CO_2 were chosen as suitable limits for the selection of samples. The accuracy of this choice was confirmed by the experiments which established the limits of composition suitable for rock wool production.

Only a small proportion of all the rock samples tested fell within the 20 to 30 per cent limits. Some of those which yielded rock wools by experimental blowing tests presented superficially the characteristics of shales, while others resembled rather pure dolomites. The use of the rapid CO_2 test proved invaluable as a means of discarding a large number of unsuitable samples.

TABLE 32—*CO_2 equivalents calculated from analyses in the literature*

Sample No.	Source of information (Bibliography)	Type	CO_2 equivalent calculated from CaO and MgO *per cent*
1	*3*	Siag wool	29.9
2	*3*	Slag wool	29.3
3	*3*	Rock wool	30.4
4	*23*	"Prior art formula"	23.5
5	*23*	"Improved formula"	17.8
6	*17*	Slag wool	21.8
7	*4*	Slag wool	26.8
8	*4*	Slag wool	26.0
9	*4*	Slag wool	23.2
10	*4*	Slag wool	27.3
11	*4*	Slag wool	27.1
12	*6*	Mineral wool	31.6
13	*6*	Mineral wool	29.6
14	*6*	Mineral wool	31.6

TABLE 33—*Calculated CO_2 equivalents of commercial wools*

Sample No.	Type	Calculated CO_2 equivalent
1	Rock wool	25.4
2	Rock wool	25.9
3	Rock wool	30.2
4	Rock wool	30.1
5	Mineral wool	26.2
6	Rock wool	28.4
7	Rock wool	25.1
8	Slag wool	22.8
9	Mineral wool	19.3

TABLE 34—*CO_2 content of Illinois woolrock samples* (*e*)
(Classification based on CO_2 content)

Sample No.	Type	CO_2* *per cent*
A-11 to A-19	Composite samples from boring	(*a*) 21.2
C-11a	LaSalle limestone	(*b*) <29.56
DS-74 (*c*)	Maquoketa shale	27.2
DX-5 (*c*)	Niagaran dolomite	25.5
DX-17A (*c*)	LaSalle limestone	(*a*) 27.38
DX-17B	LaSalle limestone	(b) <30.7

TABLE 34—CO_2 *content of Illinois woolrock samples* (*e*)—Concluded

Sample No.	Type	CO_2* per cent
La-7	Bailey limestone	(*a*) 28.05
NF-29 (*c*)	Niagaran shale	28.4
NF-46 (*c*)	Maquoketa shale	24.6
NF-56 (*c*)	Kankakee shale	24.3
NF-59a (*c*)	Niagaran dolomite	(*a*) 25.81
NF-60 (*c*)	Niagaran dolomite	26.4
NF-70 (*c*)	Bailey limestone	26.4
NF-73 (*c*)	Pennsylvanian limestone	28.5
NF-77 (*c*)	Pennsylvanian limestone	25.7
NF-79 (*c*)	Pennsylvanian limestone	25.6
NF-83 (*c*)	Pennsylvanian limestone	26.9
NF-85 (*c*)	Pennsylvanian limestone	29.6
NF-89 (*c*)	Decorah (?) limestone	24.6
NF-91 (*c*)	Bailey limestone	25.3
NF-92 (*c*)	Bailey limestone	23.2
NF-93 (*c*)	Bailey limestone	27.8
NF-94 (*c*)	Bailey limestone	28.1
NF-96 (*c*)	Niagaran dolomite	29.8
NF-99 (*c*)	Maquoketa dolomite	26.3
NF-125 (*c*)	Shakopee shale	23.6
NF-154	Niagaran dolomite	24.6
NF-155	Niagaran dolomite	26.5
NF-193	Pennsylvanian limestone	(*a*) 24.66
NF-195	Pennsylvanian limestone	(*a*) 26.48
NF-197	Pennsylvanian limestone	(*a*) 30.01
P-10	Pennsylvanian limestone	(*d*) 20.3
P-11	Pennsylvanian limestone	(*d*) 29.3
R-142	Salem limestone	(*a*) 30.00

* CO_2 by calcination unless otherwise designated.
(*a*) CO_2 by evolution, absorption, and weighing.
(*b*) Reported as "loss on ignition", temperature limits 110° to 1000° C.
(*c*) All samples so marked were successfully blown in small experimental equipment.
(*d*) CO_2 calculated from CaO and MgO content.
(*e*) For further information on samples listed, refer to Index of Sample Numbers, p. 243.

TABLE 35—CO_2 *content of Illinois sub-woolrocks* (*d*)
(Classification based on CO_2 content)

Sample No.	Type	CO_2 Content per cent
A-1 to A-10	Composite sample from boring	(*a*) 35.7
A-20 to A-33	Composite sample from boring	(*a*) 33.6
A-34 to A-47	Composite sample from boring	(*a*) 19.7
A-48 to A-56	Composite sample from boring	(*a*) 33.0
C-11b	Pennsylvanian limestone	(*b*) 32.78
DS-18	Pennsylvanian limestone	(*a*) 30.17
DS-19	Pennsylvanian limestone	34.5

TABLE 35—CO_2 *content of Illinois sub-woolrocks* (*d*)—Concluded

Sample No.	Type	CO_2 Content *per cent*
DS-33	Pennsylvanian limestone	35.2
DS-55	Pennsylvanian limestone	35.4
DS-69	Devonian limestone	(*a*) 34.73
DS-71S	Maquoketa shale	14.6
DS-72	Niagaran dolomite	(*a*) 33.76
DS-77	Maquoketa dolomite	(*a*) 36.90
DS-94	Richmond shale	17.1
DS-99	Pennsylvanian limestone	34.8
DX-4	Niagaran dolomite	34.3
DX-18	Shakopee dolomite	(*a*) 37.19
DX-19	Shakopee dolomite	34.5
DX-20	Pennsylvanian limestone	(*a*) 32.94
L-107	Niagaran dolomite	(*c*) 37.9
NF-28	Niagaran dolomite	(*a*) 37.51
NF-39	Niagaran shale	18.2
NF-58	Niagaran dolomite	37.7
NF-61	Niagaran dolomite	(*a*) 36.32
NF-68	Pennsylvanian limestone	34.1
NF-69	Pennsylvanian limestone	37.7
NF-71	Springville chert	17.3
NF-84	Pennsylvanian limestone	35.9
NF-90	Osage limestone	32.3
NF-95	Niagaran dolomite	33.6
NF-97A	Maquoketa shale	31.7
NF-98A	Silurian dolomite	33.1
NF-124	Shakopee dolomite	35.1
NF-156	Niagaran dolomite	37.1
NF-157	Niagaran dolomite	37.4
NF-158	Niagaran dolomite	33.9
NF-159	Niagaran dolomite	30.4
NF-192	Warsaw limestone	33.5
NF-196	Pennsylvanian shale	(*a*) 16.15
NF-200	Pennsylvanian limestone	31.2
E-15a	Pennsylvanian limestone	(*b*) 32.38
E-24a	Pennsylvanian limestone	(*b*) 32.9
E-24b	Pennsylvanian limestone	(*b*) 33.7
E-26	Pennsylvanian limestone	(*b*) 35.9
Bu-8	Pennsylvanian limestone	(*b*) 37.9
Bu-9	Pennsylvanian limestone	(*b*) 36.7
P-4	Pennsylvanian limestone	(*c*) 30.8
W-91	Pennsylvanian limestone	(*a*) 32.06

(*a*) CO_2 by evolution, absorption, and weighing.
(*b*) Reported as loss on ignition, temperature limits 110° to 1000° C.
(*c*) CO_2 calculated from CaO and MgO.
(*d*) For further information on samples listed, refer to Index of Sample Numbers, p. 243.

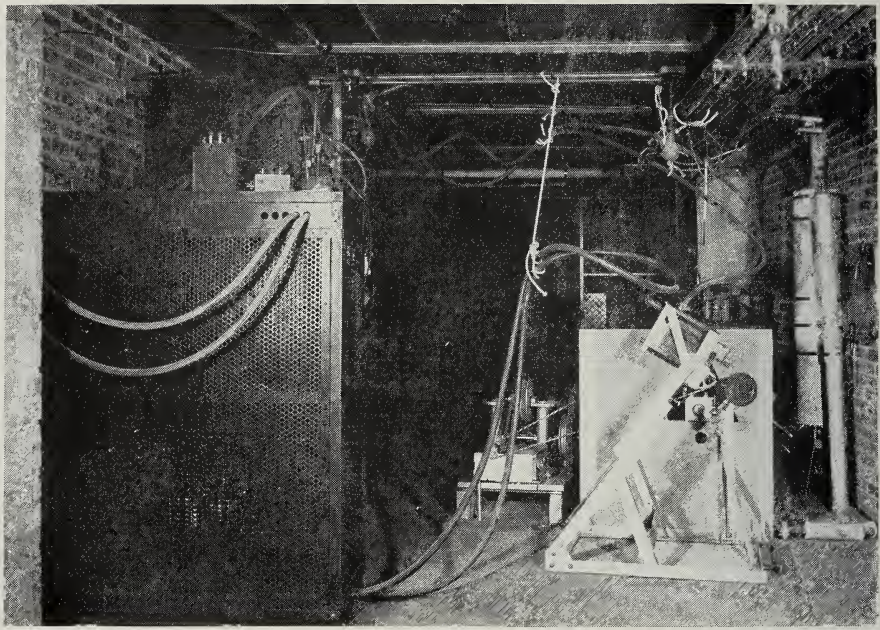


FIG. 32. Experimental blowing equipment as viewed from the wool-collecting chamber. From left to right: High frequency current generator with hydrogen testing apparatus, tilting crucible, and steam trap.

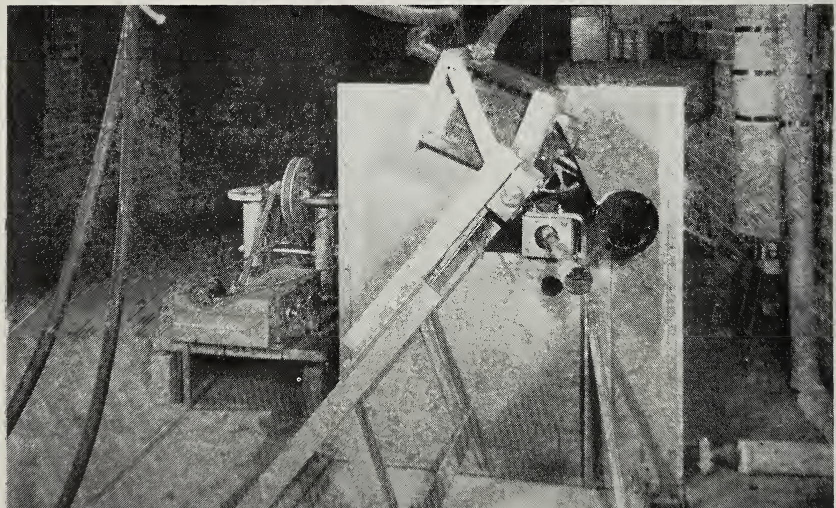


FIG. 33. View of crucible in pouring position showing arrangement of steam gun and pressure gauge.

APPENDIX III

EQUIPMENT AND PROCEDURE FOR EXPERIMENTAL BLOWING TESTS

One-kilogram samples of material were melted in a high frequency induction furnace. The 35 k.v.a. furnace, which was used, was of standard design and needs no description. It was necessary, however, to develop a suitable apparatus to pour the molten rock into the steam blast. Figures 32, 33, and 34 show views of this equipment.

Pouring Apparatus

The heating equipment consisted of a graphite crucible, 7 inches deep and 3½ inches inside diameter, contained within a water-cooled copper primary coil. It was mounted on a 2-inch brass shaft in such a manner that the crucible could be rotated around its pouring lip without interfering with the flow of electric current or water through the primary coil. The brass shaft was supported by bearings at a height of 3 feet from the floor in an angle iron frame, which was constructed in such a manner that all closed loops were insulated to minimize stray induction currents. The crucible was tilted mechanically, power being transferred to the shaft by means of a sprocket wheel and bicycle chain from a motor operated variable reduction gear. The sprocket wheel was attached to the shaft in such a manner that it could be readily disengaged by turning a threaded nut equipped with a handle. The furnace was counter-balanced by a weight carried on a steel rod attached to the shaft at an angle of 180 degrees to the crucible. This rod served also as a convenient handle for tilting the crucible manually.

Steam Gun

To prevent undue cooling of the molten stream of rock, the steam blast was directed at the molten rock stream at a point 6 inches below the pouring lip. This made it necessary to provide a steam nozzle which could be swung into position after the crucible had started to tilt. The difficulties inherent in blowing the wool were overcome by building the nozzle system in the form of a gun, which could be aimed directly at the stream of molten rock. Flexibility was obtained by mounting the gun on a 3-inch diameter ball and socket joint. The socket was adjusted by four bolts, one of which was provided with a handle. When properly adjusted, the joint could be rigidly clamped or loosely opened by a slight turn on the bolt handle. The ball and socket joint was placed directly under one of the bearings which supported the tilting shaft. The direction of the steam blast was parallel to the tilting shaft. The steam valve was mounted in a position corresponding to the trigger, and connection was made to the steam line through a length of 1-inch flexible rubber pressure hose. A small pressure gauge was mounted directly behind the nozzle orifice at such an angle that it could be seen while blowing without interfering with the view of the stream of molten rock. A stop watch was also mounted on the handle of the steam gun.

The steam nozzle consisted of a ¼-inch thick circular brass plate into which had been cut a horizontal flat slit ¾ inch long and 3/32 inch wide. To insure a smooth flow of steam into the orifice, a converging brass channel with sides sloping 10 degrees to each other, was screwed to the rear of the brass plate, and the plate in turn was placed across a short section of a 2-inch heavy walled circular steel tube, into the other end of which the steam pipe was threaded. The nozzle pressure gauge gave the pressure drop directly across the orifice. Steam under a pressure of 105 to 140 pounds per square inch was obtained from the heating system and it was found that a pressure of 70 ± 5 pounds per square inch could be held across the orifice without danger of draining the system. A rather large water trap was found to be advantageous in drying the steam.

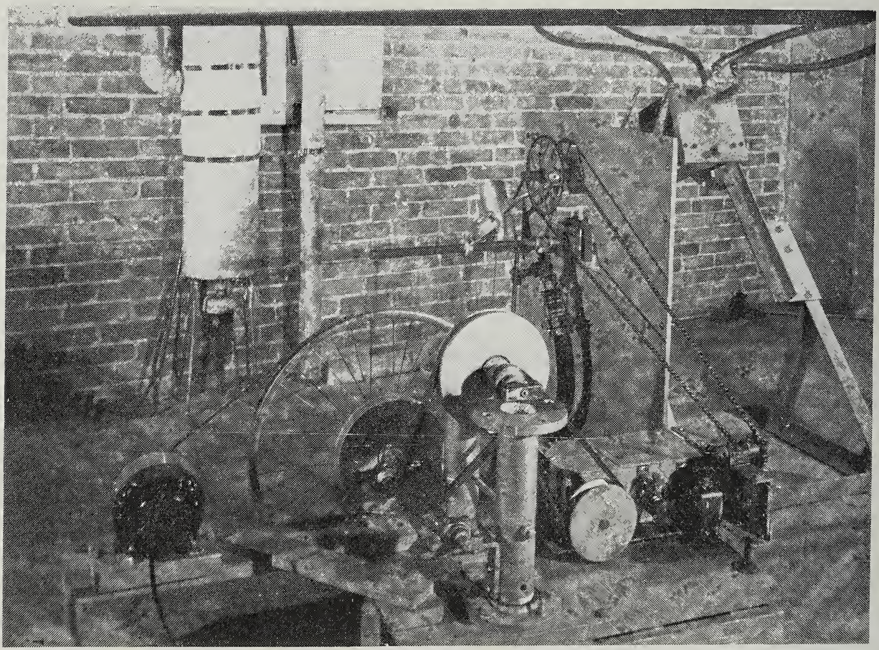


Fig. 34. Side view of tilting mechanism, and controls on steam gun.

Accessories

Graphite crucible tops about 1¼ inch thick were machined to fit the crucible tightly. Each top was equipped with a removable segment of one square inch at the pouring lip. Into this segment was screwed a ¼-inch steel rod to serve as a handle for removal before pouring. A 1¼-inch graphite thermocouple well was screwed to the bottom of the cover and extended down into the crucible. Although the crucible top attained a bright red heat during melting, undue oxidation was prevented by applying a coating of borax when hot. So treated, the top lasted as long as the crucible, which in turn was generally good for 25 experiments.

The temperature of the molten rock was measured with platinum-platinum 10 per cent rhodium thermocouple encased in a ¼-inch outside diameter porcelain tube, which in turn was inserted into the graphite thermocouple well. Compensated wire connections were made to a portable potentiometer located about 6 feet from the crucible.

The mercury interrupter used on the high frequency induction equipment works in an atmosphere of hydrogen. Hydrogen was bubbled through mercury instead of through water, as is the usual custom. Presumably this avoids a slight amount of oxidation by the water vapor at the spark gaps and thus keeps the mercury surface clean. To eliminate all danger of hydrogen explosion when the electrical current is started, a small glass eudiometer was connected to the hydrogen outlet. An explosion test, which required about 30 seconds to perform, was made just before turning on the current.

Experimental Procedure

It was found advisable to subject the rock samples to preliminary calcination before fusing in the high frequency furnace. If this were not done, large volumes of carbon monoxide were generated by reactions between both water and carbon dioxide with the hot graphite crucible. This was dangerous and it subjected the crucible to undue corrosion. Samples of rock were ground, placed in fireclay saggers, and calcined in a kiln for four hours at a temperature of from 1000° to 1050° C. This treatment saved considerable time because of the increase in speed with which the final fusions could be made.

In the usual blowing test one kilogram of calcined rock was introduced into the graphite crucible. The crucible was temporarily covered with a graphite disk. After testing the hydrogen and adjusting the flow of water required for cooling, the power was turned on and adjusted to 20 kw. As soon as the crucible charge had slumped, the graphite crucible cover containing the thermocouple well was set in place and the thermocouple was inserted. A time-temperature curve was charted from this point. When the temperature reached 1000° C. the power was lowered to about 10 kw. and shortly after was carefully adjusted to hold the temperature constant at 1500° C. for 15 minutes. This was done in all cases to insure a good fining of the charge. The temperature was then lowered, if necessary, to the blowing temperature. The temperature could be held very constant and it required only from 15 to 20 minutes to attain 1500° C.

When constancy of temperature had been attained, the thermocouple tube and lip plug were removed from the crucible cover. The tilting motor was started; the steam gun swung into position for blowing, and opened for a short blast or two to remove excess condensate. Just as the first molten material appeared at the lip of the crucible, the valve on the steam gun was opened to effect the desired blowing pressure. As the molten rock entered the steam blast, the stop watch was started. Both the pressure gauge and the aim of the steam gun required attention through the duration of the pouring. On the average, it required about 35 seconds to blow one kilogram of calcined rock.

The rock wool was blown into a room about 20 by 11 feet in size and was gathered by hand. Before each experiment the collecting room was thoroughly swept.

The location of all the controls, with the exception of those for the high frequency apparatus, was either on or close to the steam gun. This made it possible for one man to conduct the experiment.

APPENDIX IV

OBSERVATIONS ON THE DISINTEGRATION OF A MOLTEN ROCK STREAM BY A STEAM BLAST

It may be of interest to describe what happens when molten rock is poured into a steam blast; and to consider why, in some cases, a fluffy material is obtained whereas in others the rock is merely disintegrated into a large number of small spheres. The experimental blowing of rock wool is spectacular. The impact between molten rock and the blast of air or steam is accompanied by a noise which resembles the tearing of heavy cloth. A sheath of glowing material is projected from the point of impact, numerous droplets of hot material are scattered at random around the blast, while at a distance of from 10 to 20 feet from the blast nozzle, billowy masses of wool collect on the floor. Although one may observe the process intently, what actually occurs between the moment of impact and the deposition of wool on the floor has not, as yet, been thoroughly explained.

Lang (*1*) attributed the formation of fibers to the propulsion of shot which drag behind, comet like, thin threads of wool. His explanation has been widely accepted and appears to be correct. He further suggested that a discussion of the factors of surface tension and kinetic energy was desirable. In addition to this, it would appear that the problem requires a consideration of the influence of viscosity and a formulation of the transfer of momentum by impact between a turbulent steam jet and a slowly moving liquid of high density. Such a study might make possible the design of a nozzle which would convert a liquid of known composition and properties to wool, using a minimum of energy. Although a mathematical treatment seems desirable, at present only experimental observations pertaining to the blowing of mineral wool can be discussed.

Early in our investigation, experiments were conducted on the drawing of glass silk. Threads of glass were drawn from a heated glass rod and attached to an electrically driven wheel in a manner similar to that practiced commercially (*11, 24*). The higher the temperature, the finer was the silk. These threads were very fragile and broke the instant any solid material entered the molten glass at the point from which the threads were being drawn. This made it impossible to draw silk from glass which showed a tendency to devitrify. Such a behavior corresponds very closely to what is observed when blowing rock wool, since at low temperatures, or with highly viscous melts, coarse fibered material is produced. The fiber diameter of rock wool also decreases as the pouring temperature is raised.

At extremely low temperatures, the rock wool fibers were thick, measuring from 1/32 to ⅛ inch in diameter. The formation of these fibers could be readily observed and it was evident that they were generated, not comet like as pictured above, but by a direct shearing of the stream of molten rock at the point of im pact with the steam blast. The question then arose whether Lang's theory was correct, or whether rock wool may not also be produced at higher temperatures by the direct shearing action of the steam blast on the rock stream. The experimental data obtained permits of a calculation which throws light on this possibility.

About 500 grams of rock wool, with a fiber diameter of 4×10^{-6} meters and a glass density of 2.8, was produced in 35 seconds. Assuming that only half of this is wool, the other half being shot, and substituting in the formula $L = V/R^2 \pi$

gives a calculated fiber length of 7.1×10^6 meters or 4,420 miles. To shear 4,420 miles of fiber in one strand from a slag stream in 35 seconds would require a minimum steam jet velocity of 7,580 miles per minute. The maximum steam jet velocity theoretically possible from a nozzle is given by $w = 223.7 \ (i_1 - i_0)^{1/2}$, where w represents the mean velocity in feet per second, and i_1 and i_0 are the total heats of steam as given by a Mollier chart at 85 pounds and 15 pounds pressure, these pressures being the absolute steam pressures before and after expansion in our experiments. A value of 2,520 feet per second or 28.6 miles per minute is obtained. The length of the fiber produced is thus seen to be more than $7{,}580/28.6 = 265$ times too great to be accounted for on the basis of a simple shearing action exerted by the steam blast on the stream of molten rock. Thus it appears that more than 265 fibers are produced simultaneously in the blowing operation as conducted experimentally at high temperatures, and the most reasonable explanation of the phenomenon would seem to be that of shot projected through air dragging a thread of wool behind.

It is apparent, therefore, that as ordinarily conducted, the character of the blowing process undergoes a radical change within a certain temperature range. At low temperature the action of the blast is that of a simple shearing action whereby a relatively thick thread of glass is drawn from the molten rock stream. At higher temperatures shot are projected into the air and a large number of threads are produced simultaneously. It is known that the simple shearing action of a blast has been used with apparent success to produce a shot-free coarse fibered material resembling spun glass, but most mineral wools are produced by projection of shot into air.

Continuing the speculation on what occurs between the impact and deposition of the wool, consider the forces to which the molten material is subjected. In order to form a thread, the material must be subjected to a shearing action. Two such actions occur. The first occurs during acceleration by the blast. However, at the high temperature at impact, the surface tension of the liquid would appear to be greater than its cohesion, thus bringing about such changes as are commonly observed when liquids are dispersed in an atomizer. The second shearing action occurs when the particles, still hot but cooling rapidly because of their high ratio of radiating surface to volume, are projected at a high velocity into relatively stationary air. It is this latter shearing action which appears to be responsible for the production of the thin fibers. Because of rapid cooling, the surface layers collecting in the rear of the molten particles, as a result of friction with the air, are too viscous and rigid to be drawn into the particle by surface tension. This material, therefore, drags out behind in the form of a long thread. The whole process of forming the wool fibers must take place in a very short interval of time.

Morey and Bowen (*28*) observed that calcium orthosilicate (Ca_2SiO_4) cannot be quenched quickly enough to prevent crystallization. Rocks containing only small amounts of magnesia and alumina, and with a silica-lime ratio approximating that required for the formation of di-calcium silicate, could not be blown into wool. When attempted, small balls of crystallized material were obtained. This behavior might be expected. Minerals which crystallize readily exhibit a low viscosity at their melting point and their viscous range is consequently short. Such materials should retain their approximately spherical form up to the instant of solidification. This same explanation would appear to apply to the blowing of electrically fused alumina, in which operation the formation of small hollow globules is reported (*25*).

APPENDIX V

HEAT CONDUCTIVITY OF MINERAL WOOL

(A Compilation Of Data From The Literature)

The insulation properties of materials such as rock wool result from entrapping extremely small pockets of air in such a manner that heat is not transferred through air by convection. It has been found that the heat conductance of the solid portion of such a system is of slight importance. The conductance of rock wool varies with the over-all density of the material. As the density increases, the conductivity decreases to a minimum because of a decrease in size of the air pockets. Further increase in over-all density causes an increase in conductivity, the limit of which is the conductivity of the solid material. According to this point of view, the minimum conductivity must be slightly greater than the conductivity of still air.

The information to be found in the literature on heat conductivity of rock wool and mineral wool is confusing because of the various ways in which it is presented. These include arbitrary comparisons, thermal resistivities, heat conductances, and heat conductivities, all of which may be expressed either in English or metric units. The fact that the conductivity of rock wool varies according to the temperature at which it is measured and according to the degree to which the material has been compacted, does not simplify matters. Finally, the difficulties involved in measuring heat conductivities give rise to errors which make it impossible to expect close concordance between the results obtained by different investigators. Nevertheless, the information to be found in the literature affords overwhelming proof that, insofar as heat conductivity is concerned, rock wool is an exceptionally good heat insulator.

Table 36—*Heat conductivity of mineral wool at different densities and temperatures*

Reference	Material	Density (lb./ft.^{3})	Temperature °F	Heat conductivity "K"
Walker, Lewis and McAdams (13)	Mineral wool	....	70–350	0.03
Chem. and Met. (14)	Loose rock wool	10.0	90	0.023
Liddell (15)	Slag wool	....	....	0.046
Marks (16)	Mineral wool	....	....	0.035
Marks (16)	Slag wool	12	85	0.02–0.025
Marks (16)	Mineral wool	12.21	85	0.02–0.025
Guttmann (4)	Mineral wool (a)	4.81	122	0.032
Guttmann (4)	Mineral wool (a)	4.81	212	0.036
Guttmann (4)	Mineral wool (a)	4.81	392	0.044
Guttmann (4)	Mineral wool (a)	4.81	572	0.052
Guttmann (4)	Mineral wool (e)	4.31	122	0.024
Guttmann (4)	Mineral wool (e)	4.31	212	0.028
Guttmann (4)	Mineral wool (e)	4.31	392	0.038
Guttmann (4)	Mineral wool (e)	4.31	572	0.050
Guttmann (4)	Mineral wool (s)	21.3	77–262	0.06
Bur. of Standards (18)	Slag wool, loosely packed	....	77	0.0219
Bur. of Standards (19)	Slag wool	....	....	0.027
Bates (20)	Slag wool	15.4	32	0.0261

The various values presented in the literature have been recalculated in the form of heat conductivities, "K", expressed in English units, since in this form they appear to be of greatest utility (*12, 13*).

$$K = \frac{(\text{B. t. u.}) \times (\text{ft.})}{(\text{hr.})\ (\text{sq. ft.})\ (^\circ\ \text{F.})} \qquad (1)$$

The data presented in Table 36 show that under ordinary conditions the heat conductivity of rock and mineral wools varies from 0.022 to 0.03. Probably the most reliable data are 0.0219 (*18*), measured at the Bureau of Standards, for loosely packed wool, and Bates' value of 0.0261 (*20*), for slag wool with a density of 15.4 pounds per cubic foot. As the temperature is increased, the heat conductivity is increased, as shown by Guttman's data (*4*). It is not at all certain, however, that these data are comparable with the other measurements included in the table since Guttmann apparently obtained his conductivities from the Forschungsheims für Warmeschutz in Munich, while he himself determined the densities.

Table 37 presents Petavel's (*21*) data on the variation of heat loss of slag wool with compaction. Unfortunately, Petavel measured the heat conductance,

$$K' = (\text{B. t. u.})/(\text{hr.})\ (\text{sq. ft.})\ (^\circ\ \text{F.}) \qquad (2)$$

of this material, and the results are not comparable with the conductivities presented in Table 36 without knowing the thickness of his sample. In the third column, conductivities are calculated on the assumption that Petavel's samples were ½ inch thick, a value that would seem to be about correct, since $K' = K/(\text{ft.})$; where K′ is the heat conductance from (2), K is the heat conductivity from (1), and (ft.) is the linear term from the numerator of (1). If Bates' (*20*) value for K is used, (ft.) = 0.0261/0.604 ≒ 0.0432 = 0.518 inches. The fourth column presents data which were obtained by interpolation of values given in International Critical Tables (*29*).

TABLE 37—*Variation of heat loss with density*

(Calculated from Petavel's data)

Density (lb./cu. ft.)	Heat loss (K′)	Calculated heat conductivity (K); assumed thickness = ½ inch	Heat conductivity (K) from I. C. T. T = 30° C
5	0.700	0.029	—
6	0.660	0.028	—
7	0.617	0.026	—
8	0.580	0.024	—
9	0.557	0.023	.022
10	0.543	0.023	.023
11	0.550	0.023	.023
13	0.564	0.024	.024
15	0.604	0.025	.025
19	—	—	.028

In Table 38 the conductivity of mineral wool in the various forms in which it is fabricated is compared with similar values for other insulating materials. The data are taken from Chemical and Metallurgical Engineering (*14*).

TABLE 38—*Heat conductivity of various insulating materials*

Material	Density (lb./cu. ft.)	Temp. ° F.	"K"
Rock cork, slabs, asphalt binder	15.6	86	0.027
Rock wool filling—loose	10.0	90	0.023
Rock wool filling—granulated	9.42	156	0.024
Rock wool, felted—blankets	8.2	300	0.034
Rock wool, felted—with metal jackets	19.4	400	0.044
Rock wool, felted sheets, molded with clay and asbestos	15.2	200	0.032
Rock wool cement	30.0	500	0.085
Diatomaceous earth bricks	27.7	1600	0.077
Spun glass blanket	5.56	400	0.043
85 per cent magnesia pipe covering	14.5	400	0.046
Corkboard slabs	7.0	——	0.023
Bauxite molded with clay	33.0	1600	0.100
Still air	0.08	32	0.013

In Table 39 the variation of heat conductivity of glass silk with temperature and density is presented. Similar data have been interpreted in the literature (*11*) as indicating that glass silk shows the lowest heat conductivity of any heat insulator, but a comparison of the values given in Table 39 with those of Table 36, 37, and 38 shows that this contention cannot be sustained. As might be expected, the minimum heat conductivity of glass silk is about the same as that of mineral wool. Apparently the minimum heat conductivity for glass silk occurs at a lower gross density than for rock wool.

TABLE 39—*Heat conductivity of glass silk*

Reference (Bibliography)	Density (lbs./cu. ft.)	Temperature ° F.	"K"
(*11*)	——	32	0.020
	——	122	0.025
	——	212	0.029
	——	392	0.038
	——	572	0.047
(*20*)	8.32	32	0.026
	7.44	32	0.025
	4.56	32	0.023
	4.06	32	0.023
	3.18	32	0.025
(Air only with convection)	0.08	32	0.076

BIBLIOGRAPHY

1. Herbert Lang, "Some problems encountered in designing and operating a slag wool plant." Chem. and Met. Eng. *29*, No. 9, p. 365, 1923.
2. J. R. Thoenen, "Mineral wool and cement from a silicified lime rock." Rock Products, pp. 39-41, Feb. 21, 1925.
3. J. R. Thoenen, "Mineral wool." Information Circular 6142, U. S. Dept. Commerce, Bur. of Mines, June, 1929.
4. Arthur Guttmann, "Verwendbarkeit und Eigenschaften von Schlackenwolle." Stahl und Eisen *49*, 97, Jan. 24, 1929.
5. M. F. Goudge, "Raw materials for the manufacture of rock wool in the Niagara peninsula of Ontaria." Memo. Ser. No. 50, Mines Branch, Dept. of Mines, Ottawa, Canada, Aug., 1931.
6. W. N. Logan, "The mineral wool industry in Indiana." Preprint, Amer. Inst. Min. Met. Eng., Feb., 1932.
7. A. Koberle, "Means for blowing mineral wool." U. S. Patent 1,650,136, Nov. 22, 1927. Assignor to L. & W. Corp.
8. T. B. Parkison, assignor to Union Fiber Co., U. S. Patent 945,583, Jan. 4, 1910.
9. Wm. Fay, U. S. Patent 1,256,541, Feb. 19, 1918.
10. Popular Mechanics *36*, 97, July 1921.
11. A. D. Saborsky, "Glass wool heat insulation in Europe." Jour. Amer. Cer. Soc., *6*, pp. 674-684, May, 1923.
12. Badger and McCabe, "Elements of Chemical Engineering." McGraw–Hill Book Co., p. 117, 1931.
13. Walker, Lewis, and McAdams, "Principles of Chemical Engineering," McGraw–Hill Book Co., 2nd Ed., 1927, p. 119.
14. Chem. and Met. Eng. *39*, p. 658, 1932.
15. D. M. Liddel, "Metallurgists' and Chemists' Handbook." McGraw–Hill Book Co., 3rd Ed., 1930, p. 166.
16. L. S. Marks, "Mechanical Engineers' Handbook," McGraw–Hill Book Co., 2nd Ed., 1924.
17. Green and Edwards, Gas J. (Lond.) Sup. 23-27, July 22, 1925.
18. Sheet Metal Worker, Dec. 5, 1924, p. 861.
19. H. M. Stat. Office, Kingsway, Lond. W. C., Spec. Rep. No. 5, 1922. See also Analyst *47*, pp. 119-122.
20. H. C. Bates, "Glass wool as insulator for refrigeration purposes." Jour. Amer. Cer. Soc., *9*, pp. 690-692, 1926.
21. R. Glazebrook, "Dictionary of Applied Physics," Vol. I, p. 431, 1922.
22. Isola-Gesellschaft. German Pat. 473,821, April 30, 1926.
23. E. R. Powell, U. S. Patent 1,656,828, Jan. 17, 1928.
24. Chem. and Met. Eng., *37*, No. 8, p. 480, 1930.
25. Edwards, Frary, and Jeffries, "The Aluminum Industry," McGraw–Hill Book Co., N. Y., 1930, 2 vol.

26. Hillebrand and Lundell, "Applied inorganic analysis." John Wiley & Sons, 1929.
27. John E. Teeple, Jour. Ind. and Eng. Chem. *14*, p. 904, 1922.
28. G. W. Morey and N. L. Bowen, Jour. Soc. Glass Tech., *9*, p. 228, 1925.
29. International Critical Tables, II, p. 312. McGraw-Hill Book Co., N. Y., 1927.
30. A. N. Winchell, "Microscopic Character of Artificial Minerals." John Wiley & Sons, p. 328, 1931.
31. International Critical Tables, IV, p. 93.
32. Richard S. McCaffery. Tech. Pub. 383, Amer. Inst. Min. Met. Eng., 1931.
33. "Thermal Insulation of Buildings," Circular No. 376, U. S. Bureau of Standards.
34. E. C. Eckel, "The manufacture of mineral wool," Mineral Industry XI, 470-476, 1903.

INDEX TO SAMPLE NUMBERS

INDEX

A

B